How can I ...

design a small reliable I/O system

Tested Validated Documented Architecture

Industrial Ethernet Networks

Develop
your project

Schneider Electric

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Disclaimer

This document is not comprehensive for any systems using the given architecture and does not absolve users of their duty to uphold the safety requirements for the equipment used in their systems or compliance with both national and international safety laws and regulations.

Readers are considered to already know how to use the products described in this document.

This document does not replace any specific product documentation.

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The TVDA collection

Tested Validated Documented Architectures (TVDAs) are designed to help project engineers and Alliance System Integrators during the development of a project. The TVDAs support users during the architecture selection and the project execution phases with an introduction to the system operating modes.

Each TVDA is a starter kit that can provide users with:

- Technical documentation
- Application examples
- Object libraries

Each TVDA addresses one or several customer challenges within the proposed solution using the offer from Schneider Electric.

All explanations and applications have been developed by both Schneider Electric experts and system integrators in our solution labs. The contributions from the system integrators help the kit's content meet the expectations of our users.

All TVDAs are illustrated with industry-specific applications to give more concrete examples of the methodology.

TVDAs are not intended to be used as substitutes for the technical documentation related to the individual components, but rather to complement these materials and training.

Development environment

Each TVDA has been developed in one of our solution platform labs using a typical PlantStruxure architecture.

PlantStruxure, the Process Automation System from Schneider Electric, is a collaborative system that allows industrial and infrastructure companies to meet their automation needs while also addressing growing energy management requirements. Within a single environment, measured energy and process data can be analyzed to yield a holistically optimized plant.

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1. Introduction

1.1. Purpose

The purpose of this Tested Validated Documented Architecture (TVDA) is to present the design and performance of a standalone I/O system. The system incorporates an M340 PLC as the controlling device, using the Modbus TCP protocol and STB I/O as the remote devices.

This TVDA will provide the following:

- Network design that should be used for a small I/O system
- Network architectures to prevent data interruption due to a cable break or an inoperable device
- The overall performance of the specified system

1.2. Customer challenges

When installing a new system, customers desire a cost-effective, simple system that provides network redundancy and reliable communication. They need more than a simple proof of concept. Customers must be confident that a system will work and perform within the expected operating range prior to purchasing and installing products.

This TVDA addresses these challenges by recommending an appropriate network architecture and providing the performance results from the specified network.

1.3. Skill set prerequisites

The reader will benefit from this document if they are already familiar with the following software applications and networking concepts.

Software applications:

- Unity Pro
- Advantys Configuration Software
- Vijeo Citect

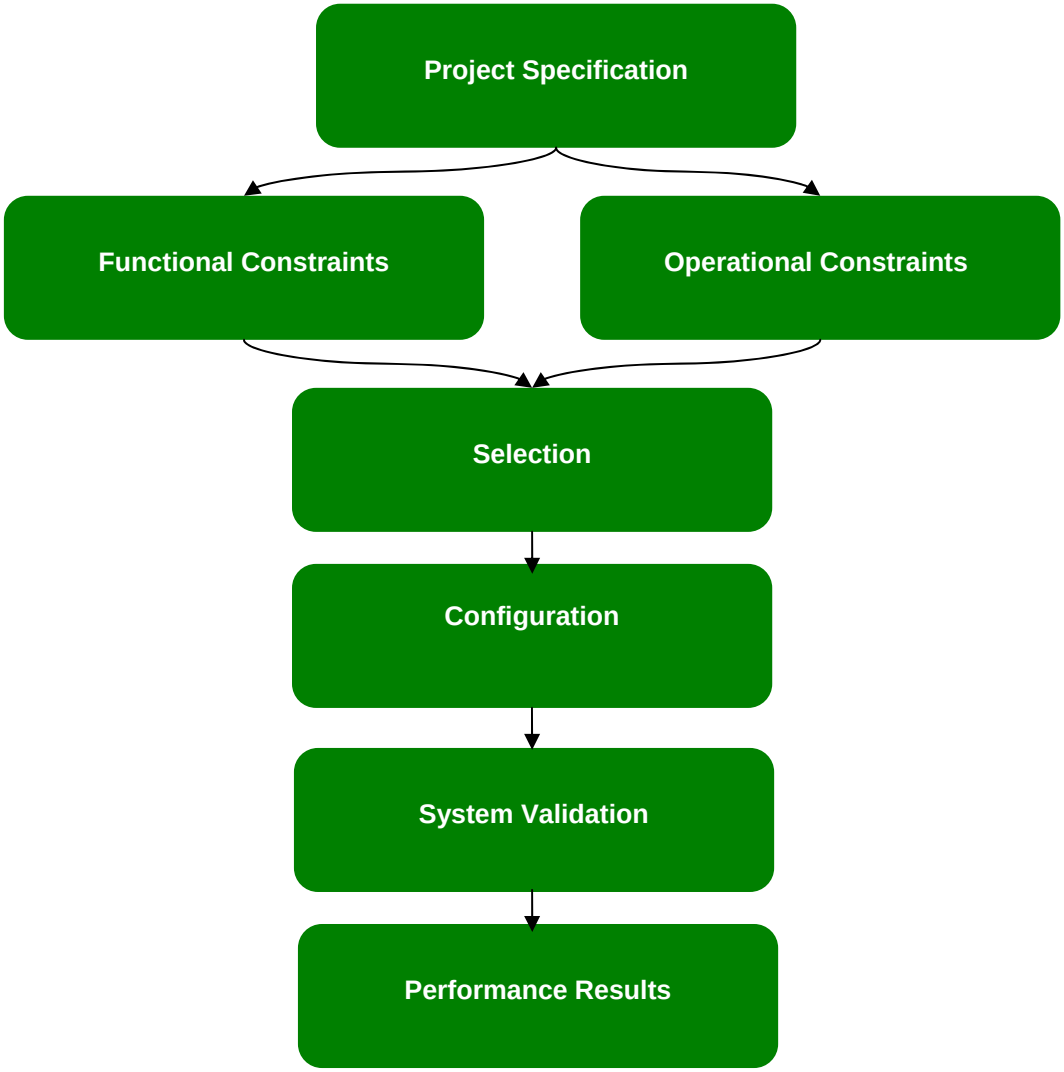
Ethernet knowledge:

- Basic Ethernet networks
- Basic understanding of network redundancy principles
    - Rapid Spanning Tree Protocol (RSTP)

1.4. Project methodology

This TVDA will guide the user through five phases: selection, design, configuration, implementation, and performance.

During the selection phase, an effective architecture needs to be chosen for the specified devices. Various architectures and systems are presented here. The system that best satisfies the requirements will be the one that will be chosen for testing. The following chart illustrates our system design approach; each aspect will be addressed in the following sections:



2. Selection

During the selection phase, an effective architecture needs to be chosen as well as the appropriate components for the project, according to your specific requirements. The requirements for this small stand alone I/O system are to provide a high availability system while being simple to maintain and cost effective. After examining various products within Schneider Electric's solution offerings, the following two products are considered to be well suited for this system and its requirements.

The BMX NOC 0401 module offers an embedded switch with four ports for Ethernet communications. Transparent to the user, the module can process both Modbus TCP and EtherNet/IP messages. (This TVDA concentrates on the Modbus TCP capabilities of the module). RSTP is a key feature supported by this module which becomes an integral part of a reliable I/O system.

The STB NIP 2311 is a dual port Ethernet communication module with an embedded switch that supports RSTP, allowing a designer to establish a daisy chain loop or ring topology. This module supports Modbus TCP and can be configured via Advantys Configuration Software.

In the following section, some network topology options are considered, and one is chosen as the focus of this TVDA.

Designation	Reference	Firmware versions	Quantity
4 Port M340 Ethernet Communication module	BMX NOC 0401	v1.0	1
Dual Port STB Ethernet module for Modbus TCP	STB NIP 2311	V3.0	10

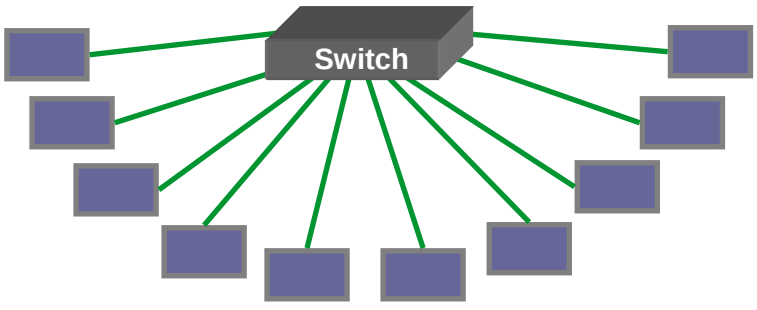
Table 1. Device Version Information

2.1. Network topology

Many different topologies are available for the products specified above. In the following section we will examine each of the topologies and evaluate them against our required attributes: *simplicity*, *redundancy*, and *cost*

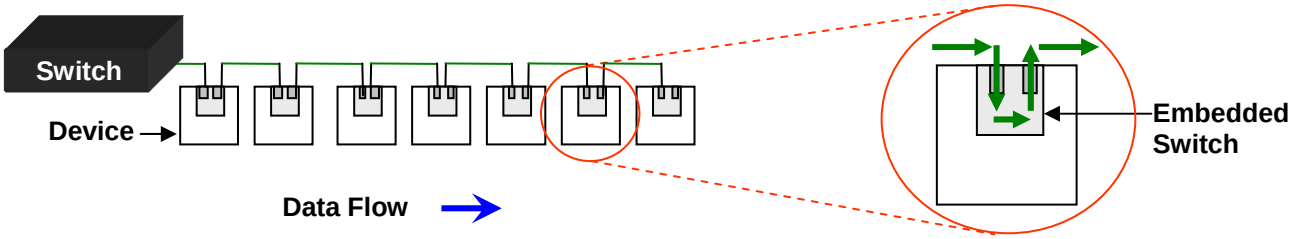
2.1.1. Star

In a star topology all the devices are connected through a central device. This is an efficient use of network bandwidth because it spreads the traffic out through the star network. A broken cable or an inoperable device does not affect other devices on the network. However, a star topology does not provide redundancy, and a broken cable or inoperable device becomes a single point of failure for any devices that follow it on the network If the switch itself fails, all communication is lost. Additionally it is not very cost-effective since each device requires an individual cable connection back to the switch.

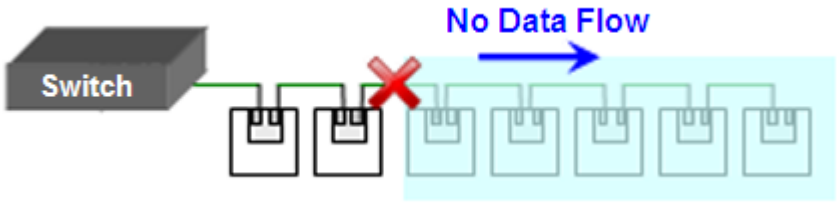


2.1.2. Daisy chain

The daisy chain topology has evolved from the bus architecture. Each device has an embedded switch, so an external switch is not needed. Although this saves money (by eliminating external switches and long cabling), it does not address redundancy.

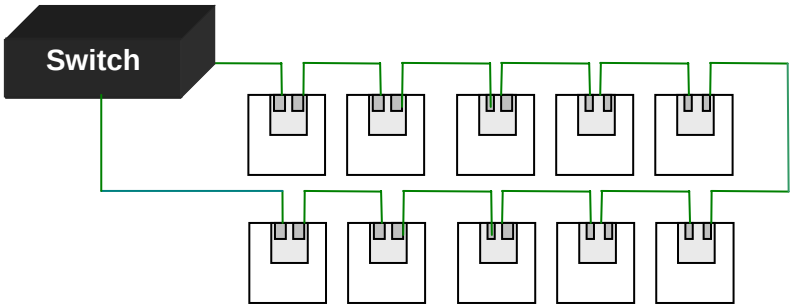


If a link between two devices is broken, then communication to all devices beyond the affected link is no longer possible.



2.1.3. Daisy chain loop using RSTP

One way to solve communication interruption in a daisy chain network is to modify the network to create a daisy chain loop and implement a ring redundancy protocol such as RSTP. RSTP is an OSI layer 2 protocol defined by IEEE 802.1D 2004. As soon as it detects a redundant physical link in the network, it creates a logical loop-free tree structure topology. If RSTP is used in a ring topology with 10 to 20 devices, the network can recover from a broken wire or inoperable device in a matter of milliseconds.



2.2. Selection criteria

The star network topology is well known, but it lacks redundancy and cost-effectiveness. The daisy chain network topology simplifies the network layout and reduces cost, but it does not provide redundancy. A daisy chain ring managed by a ring redundancy protocol is the one topology that addresses all three concerns for the required system.

	Simplicity	Redundancy	System Cost
Star	✗	✗	✗
Daisy Chain	✓	✗	✓
RSTP Ring	✓	✓	✓

Table 2. Network Topology Benefits Comparison

2.3. Device IP address assignment

When considering various methods of assigning IP addresses to I/O devices in the system, the method chosen must be reliable with as few steps as possible. The STB NIP 2311 supports:

- Option 1: MAC-based default IP address 10.10.MAC.MAC
- Option 2: Static IP address via the Advantys Configuration Software
- Option 3: Static IP address via the STB NIP 2311 web pages
- Option 4: Served IP address via BootP server
- Option 5: Served IP address via DHCP server

For more detailed information regarding steps for each procedure please refer to STB NIP-2311 user guide, EIO0000000051.

Option 1: MAC-based default IP address

In general, plants do not use the default IP address of a device in the operating plant environment. The device must be given a new IP address. Once this new and unique IP address has been assigned, the module can be configured as required. The following will outline the general steps required to assign the IP address to the STB NIP 2311 using the options mentioned above.

Option 2: Static IP Address Assignment via Advantys Configuration Software	
1	Adjust the rotary switches in front of the new module to **Stored**.
2	Connect to the module using a serial connection. If you are connecting through the Ethernet port, the IP address of the PC must be on the same subnet as the default IP address of the STB NIP 2311 module, 10.10.MAC.MAC.
3	Use the Module Editor to modify the IP address of the STB NIP 2311.
4	Save the configuration to the module by downloading its configuration.

Table 3 – Static IP Address Assignment via Software

Option 3: Static IP Address Assignment via STB NIP 2311 Web Pages	
1	Adjust the rotary switches in front of the new module to **Stored**.
2	Change the IP address of your PC to 10.10.X.Y so that it is on the same network as the STB NIP 2311 default IP address. This will enable you to access the web pages of the new device
3	Access the embedded web pages of the device by entering the device's default IP address in a web browser. Enter the new IP address and save the new IP parameters.
4	Change PC's IP address back to its original IP address. This will enable it to communicate to all the devices on the network.
5	Place the module back on the network. When it powers up, the module will use the stored IP address configured via embedded web page.

Table 4. Static IP Address Assignment via Web Page

Option 4: Served IP Address via BootP Server	
1	Obtain the MAC address of the STB NIP 2311 island at boot-up.
2	Edit the BootP server, and remove the MAC address of the device to be replaced. Enter the MAC address of the new device that needs to obtain an IP address.
4	Adjust the rotary switches in front of the module to **BootP**.
3	Place the new device on the network

Table 5 – IP Address Assignment via BootP Server

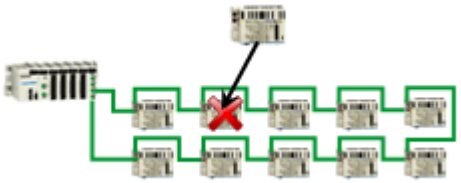
Option 5: Assignment via DHCP server	
1	Adjust the rotary switches of the new STB island to the same device name as the STB island that is being replaced.
2	Replace the previous device with the new device.
	

Table 6. Served IP Address Assignment via DHCP

The issue with assigning static IP addresses is that the IP address resides with the module's configuration. If the module is replaced with a new module the entire process of assigning an IP address must be repeated each time.

You can save a significant amount of time and resources by using either the FDR service or an address server to automate the task for you. The address server already has the device name as part of its configuration. By giving the replacement STB NIP 2311 the same device name, the module is able to obtain its IP address from the address server.

During a plant startup, this becomes a key feature. Imagine the time and resources saved when more than 50 devices must obtain their IP addresses.

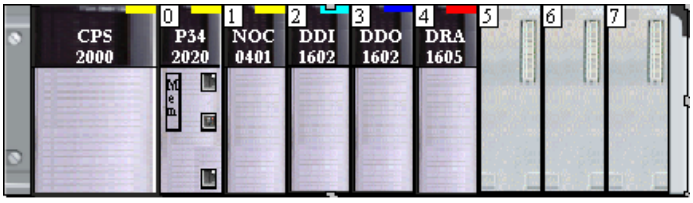
Assigning IP addresses via DHCP (option 5) simplifies configuration and maintenance and saves project installation startup time. The system we recommend in this TVDA uses the BMX NOC 0401 as the DHCP server; it provides all the STB islands with their IP parameters.

3. Design

3.1. Products used

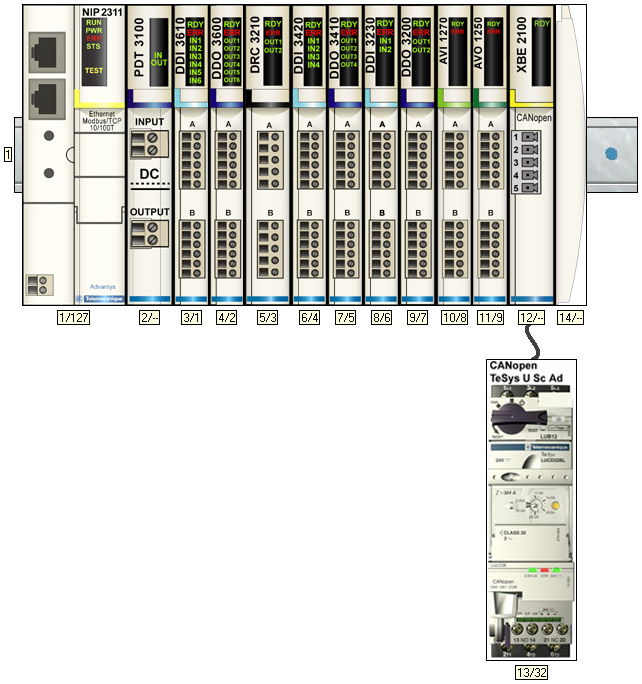
The following is the list of products will be used to construct the small stand alone I/O system

M340 PLC Platform:



- BMXCPS2000
- BMXP342020
- BMXNOC0401
- BMXDDI1602
- BMXDDO1602
- BMXDRA1605

Modicon STB islands with dual port Modbus TCP:



- STBNIP2311
- STBPDT3100
- STBDDI3610
- STBDDO3600
- STBDRC3210
- STBDDI3420
- STBDDO3410
- STBDDI3230
- STBDDO3200
- STBAVI1270
- STBAVO1250
- STBXBE2100
- TeSys U

Cables:

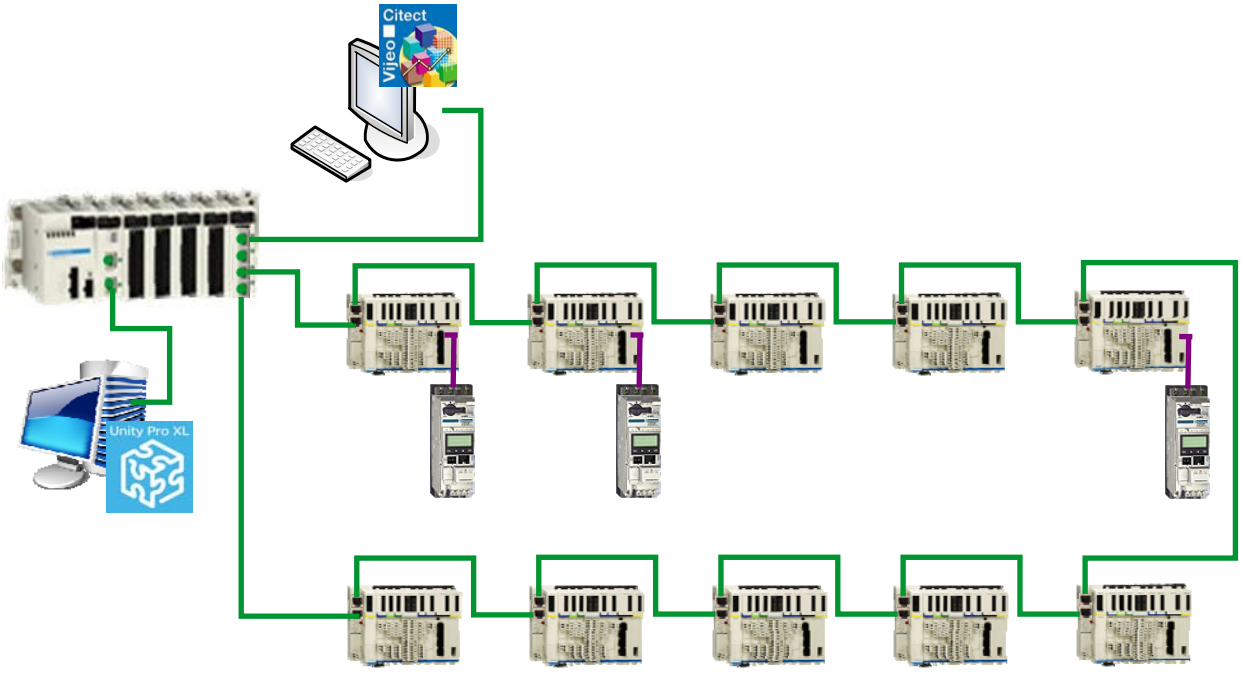
- M340 programming Cable
- Ethernet CAT5e cables

Software:

- Unity Pro XL v5.0
- Unity Pro Ethernet Configuration Tool v1.0
- Advantys Configuration Software v4.7.0.4
- Vijeo Citect v7.1

3.2. Suitable network topology for small standalone I/O system

To achieve reliability in the I/O network, the BMX NOC 0401 Ethernet communication module is used as the main switch. By enabling RSTP in the communication module, ports 3 and 4 can participate in the daisy chain ring.



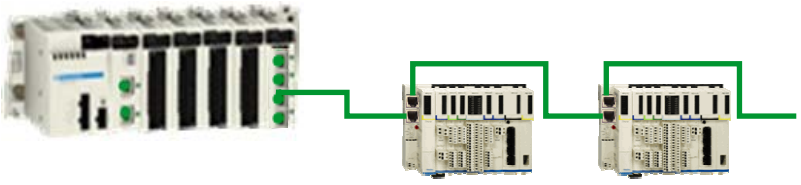
Architecture chosen for Small Stand Alone I/O System

3.3. Installation guidelines

Below is an installation quick start sequence for assembling the system. Refer to the product user manual for detailed information on the products used.

- Assemble all the I/O modules.
- Wire all I/O modules to required motor starters.
- Use the rotary switch on each of the Modicon STB modules to assign the device names.
- Starting with the BMX NOC 0401 Ethernet module, connect port 3 to the bottom port of the first Modicon STB I/O module, then connect the top port of the first STB I/O module to bottom port of the second STB I/O module.

Note: Do not connect the last STB to port 4 of the BMX NOC 0401 Ethernet module. The last link is connected after the Ethernet module has its configuration.



3.4. Functional requirements

Certain parameters need to be considered before you set the values. Typically, CPU scan time is driven by the application; however, the frequency of requests sent to remote devices can be chosen. The repetitive rates that you configure should meet the application's performance needs. As a rule of thumb, the data being requested should be updated twice during a CPU scan. This system requires a 50 ms CPU scan time. Therefore, the repetitive rate is configured for 20 ms.

CPU scan	50 ms
Repetitive rate	20 ms

4. Configuration

Both Unity Pro v5.0 and the Unity Pro Ethernet Configuration Tool must be used to configure the (4-port) M340 Ethernet Communication module. The STB islands are configured via the Advantys Configuration Software. The overall system SCADA is created using Vijeo Citect software.

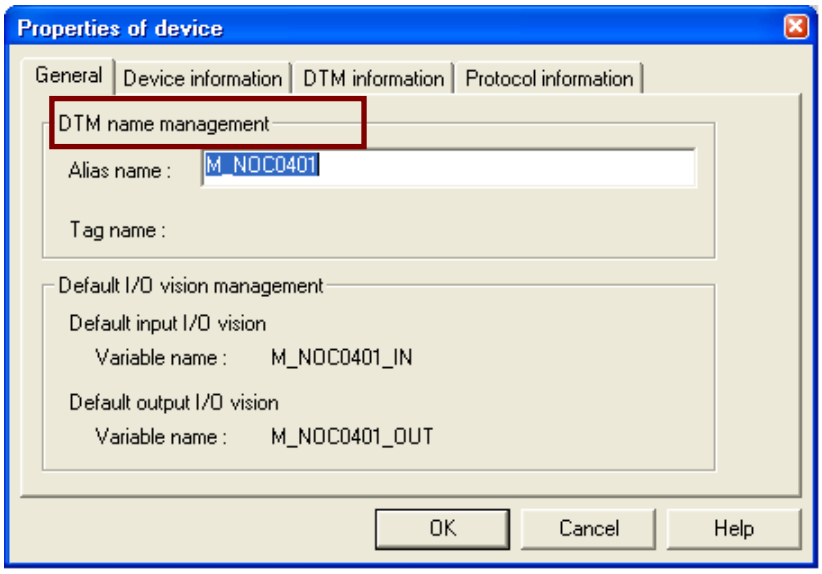
This section provides the essential steps to configure the hardware. As mentioned in the prerequisites for the document, user should be sufficiently familiar with Unity Pro, Advantys Configuration, and Vijeo Citect software applications to create basic projects. Reference the pertinent user manuals if you need more information.

4.1. M340 Ethernet communication module

In Unity Pro software, create a new project for the M340 platform, and populate the PLC bus with the appropriate CPU and the I/O modules.

By default the CPU reserves 1024 words You will need to increase this amount for the BMX NOC 0401 and SCADA usage. To do this, double click on the CPU and increase the %MW size in the Configuration tab. Here is more detail about how to configure the BMX NOC 0401 Ethernet module:

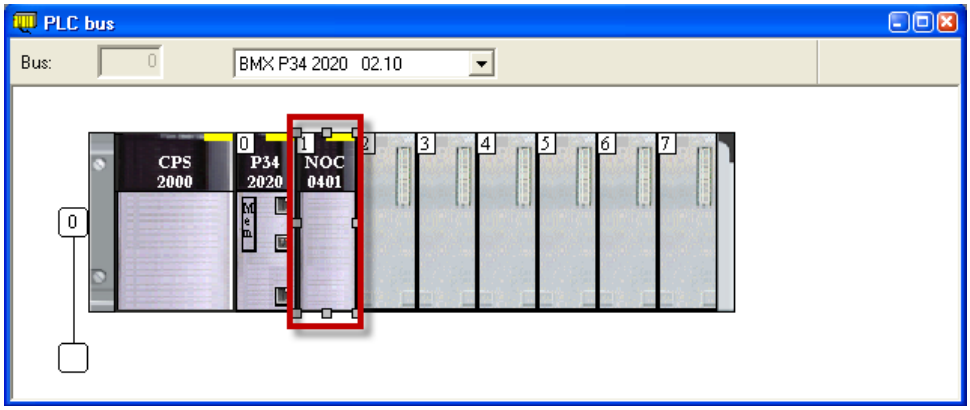
1. After you have started a new project in Unity Pro software, open the Project browser, and double click on the PLC bus,
2. In the Hardware Catalog, open the communication folder, find the BMX NOC 0401 module in the list, and add it to the rack.
3. Once you place the module in the desired slot, a window will pop up requesting that an Alias name for the module. Use the default name or change it per the plant's naming convention.
4. Click OK.



BMXNOC0401 Module Properties Window

The module is then placed in the rack and ready to be configured.

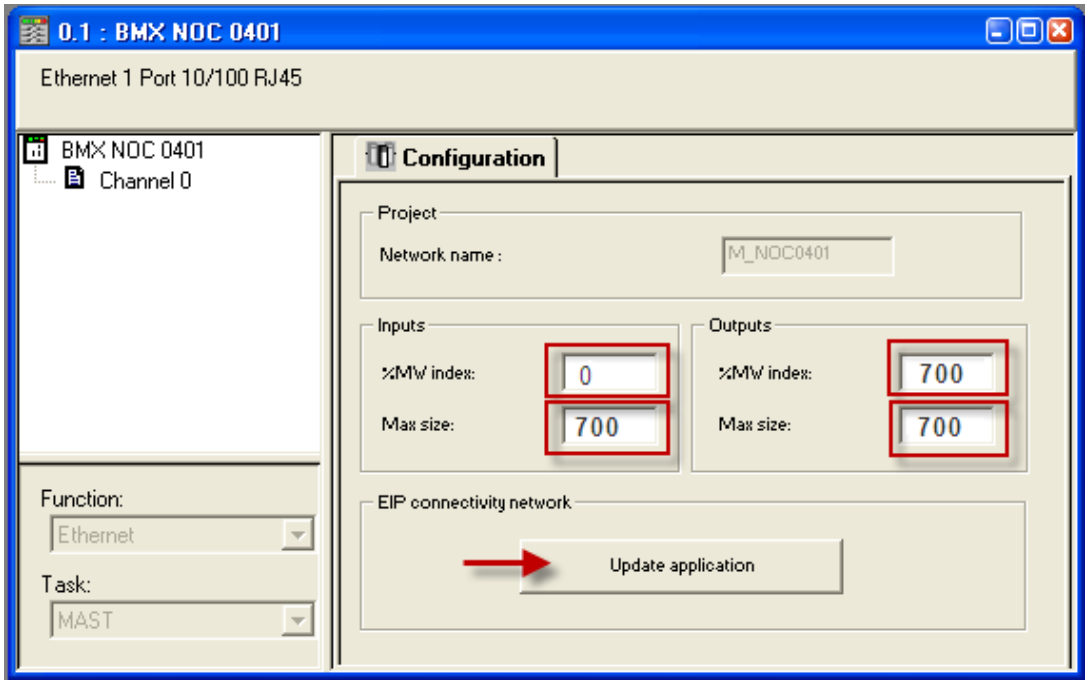
5. Double click on the module to configure the M340 Ethernet module memory location and size.



Unity Pro – PLC bus

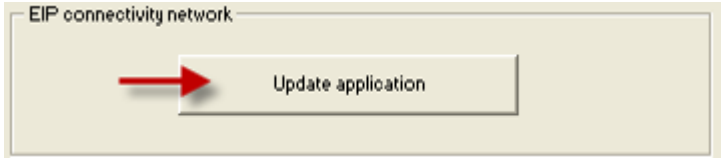
6. In the Configuration screen, assign the starting locations of the input and output registers and their respective sizes. Sixteen registers are reserved in the input and output memory locations for a *connection health bit* and a *connection control bit*, respectively.

7. The input and output starting indices and memory size for each of the parameters can be configured. For this application the following parameters were used:

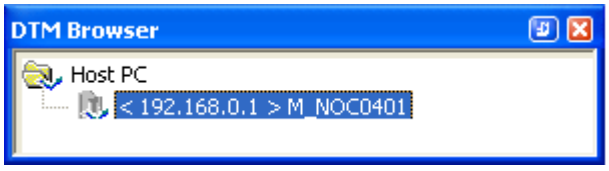


Unity Pro –BMX NOC 0401 Default Configuration

8. Once the modifications are done, click the **Validate** button. The **Update application** button will become highlighted and the project can be updated with the M340 Ethernet module's memory allocation configuration.



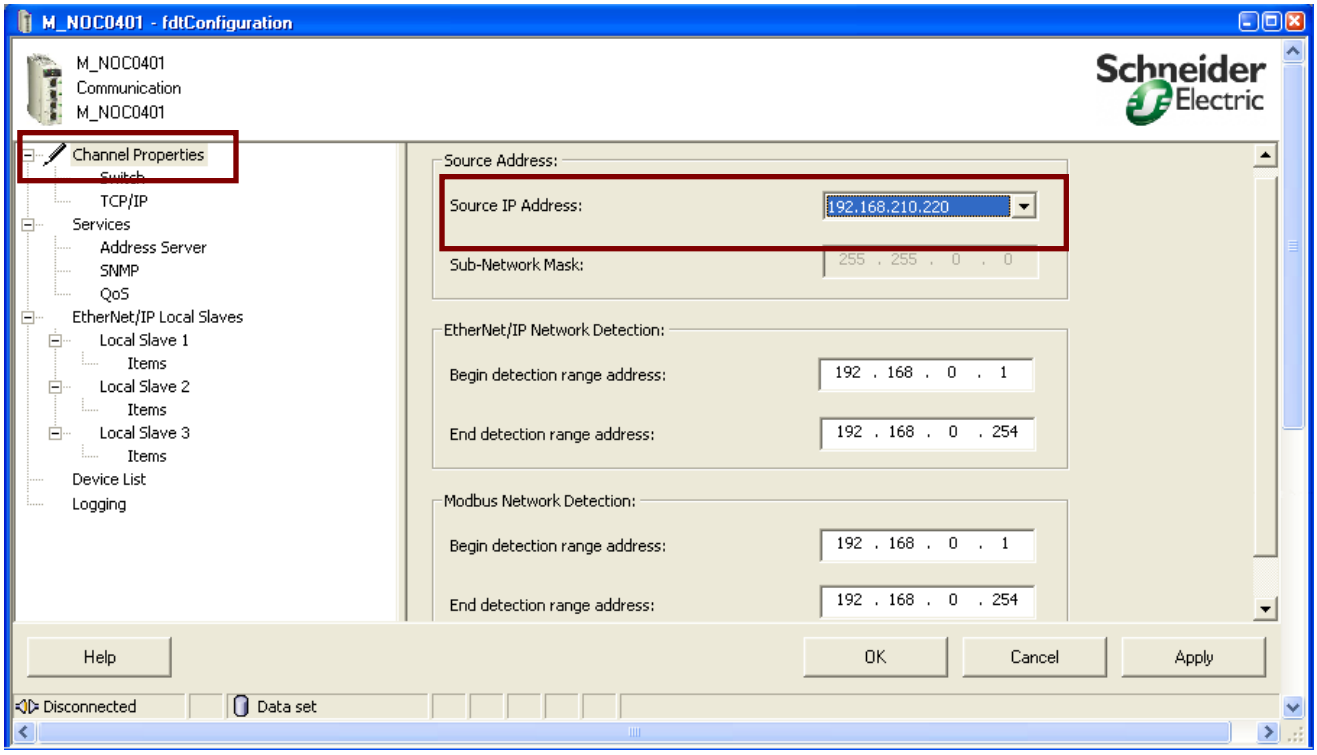
9. Complete the configuration set up in the DTM Browser by choosing the **Tools** pull down menu and select **DTM Browser**.



10. Double click on the M_NOC0401 to launch the DTM. The remaining configuration can be completed.

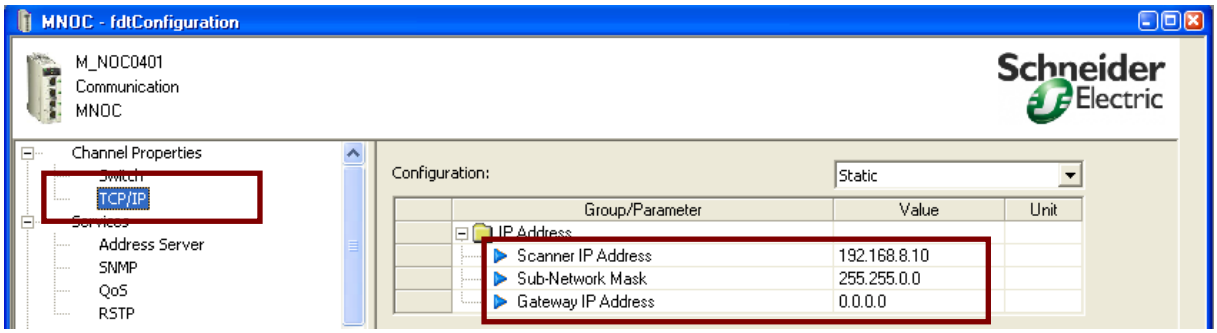
4.1.1 Channel properties

Some items in the **Channel Properties** menu need to be selected and modified. If the PC has more than one network card, use the **Source IP Address** pull down option to choose the IP address that is associated with the same network as the M340 Ethernet communication module.



Ethernet Configuration Screen within Unity Pro

In the sub-tree option **TCP/IP,** you can assign the IP address, sub-network mask and gateway for the BMX NOC 0401 Ethernet module.



4.1.2. Services

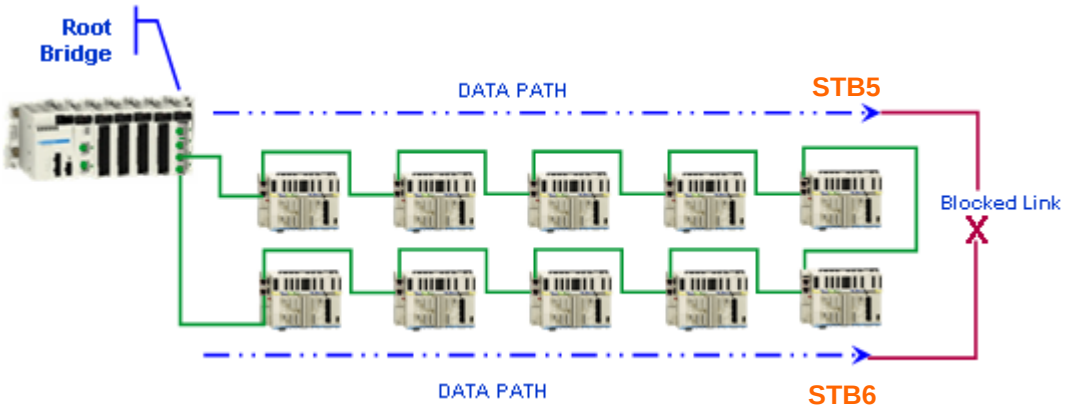
Multiple parameters in the **Services** menu also need to be configured. The following topics step you through the RSTP, data exchange, and the address server setup.

4.1.2.1 RSTP

RSTP functionality is enabled in the **Services** section of configuration screen. Once RSTP is enabled, a sub-tree option is displayed with additional parameter settings. One of these parameters, Bridge Priority; is used to identify which device in the network will act as the root of the RSTP tree. The *root bridge* in the RSTP network has the lowest bridge ID. To compare two bridge IDs, the priority is compared first. If two bridges have equal priority, then the MAC addresses are compared. In our network, the BMX NOC 0401 will be the root bridge. The STB NIP 2311 modules by default have a high number assigned for Bridge Priority. Accepting this default value identifies the BMX NOC 0401 as the root, and the branches of the tree will be distributed symmetrically.

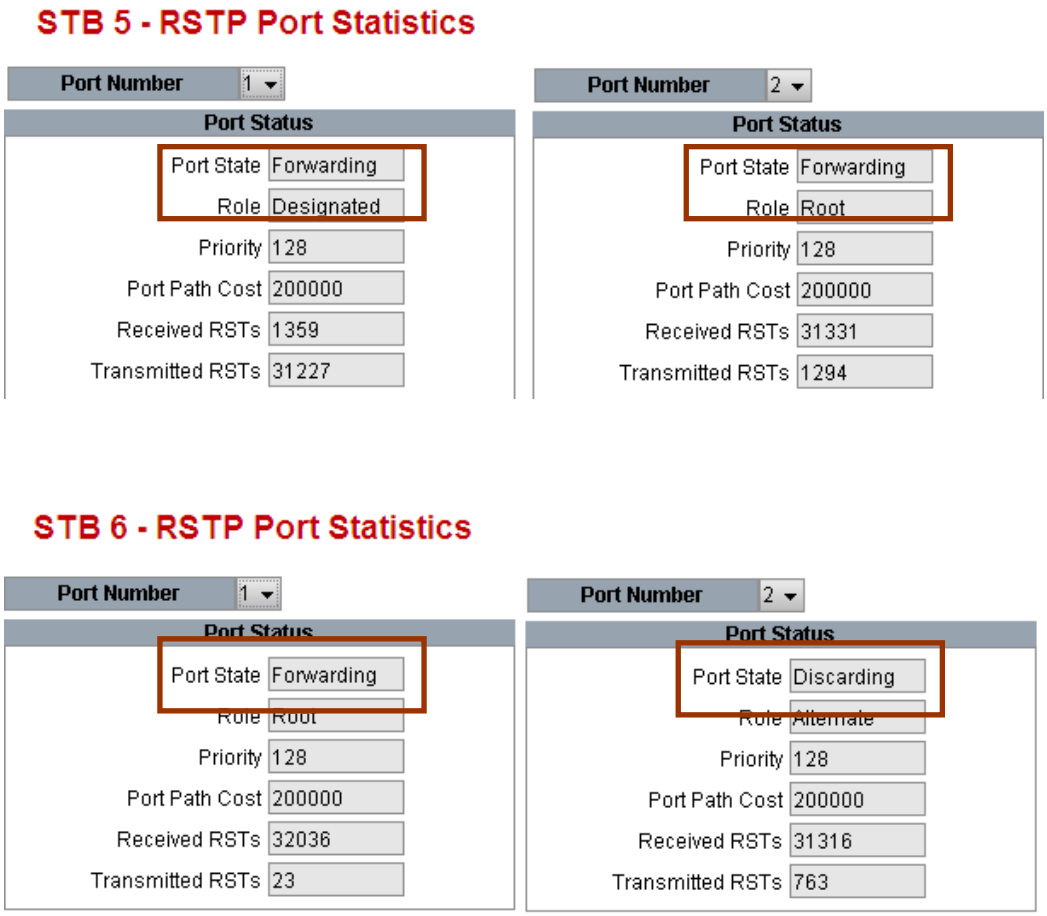
Note: Bridge ID is a combination of the Bridge Priority and the MAC address.

Refer to RFC 802.1D 2004 for more information on Bridge role and its parameters.



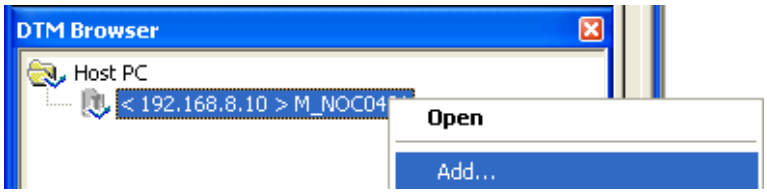
RSTP Service and Data Flow

In a simple network where an even number of devices are being managed, it is likely that the link at the half-way point will be blocked. In the above system by looking at the web pages for STB5 and STB6 it was confirmed that the path between the two devices is blocked as indicated by the **Discarding** state on port 2 of STB6.

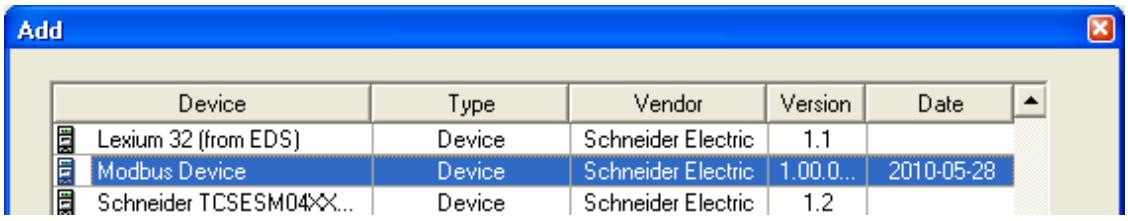


4.1.2.2 Add devices to be scanned

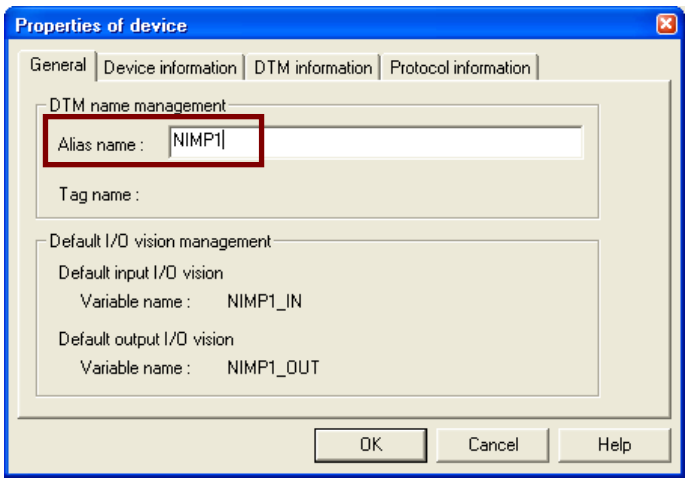
Devices that you want to be part of the Ethernet module's configuration must be added to the device list. From the **DTM Browser**, right click on the M_NOC0401 Ethernet module and select **Add**.



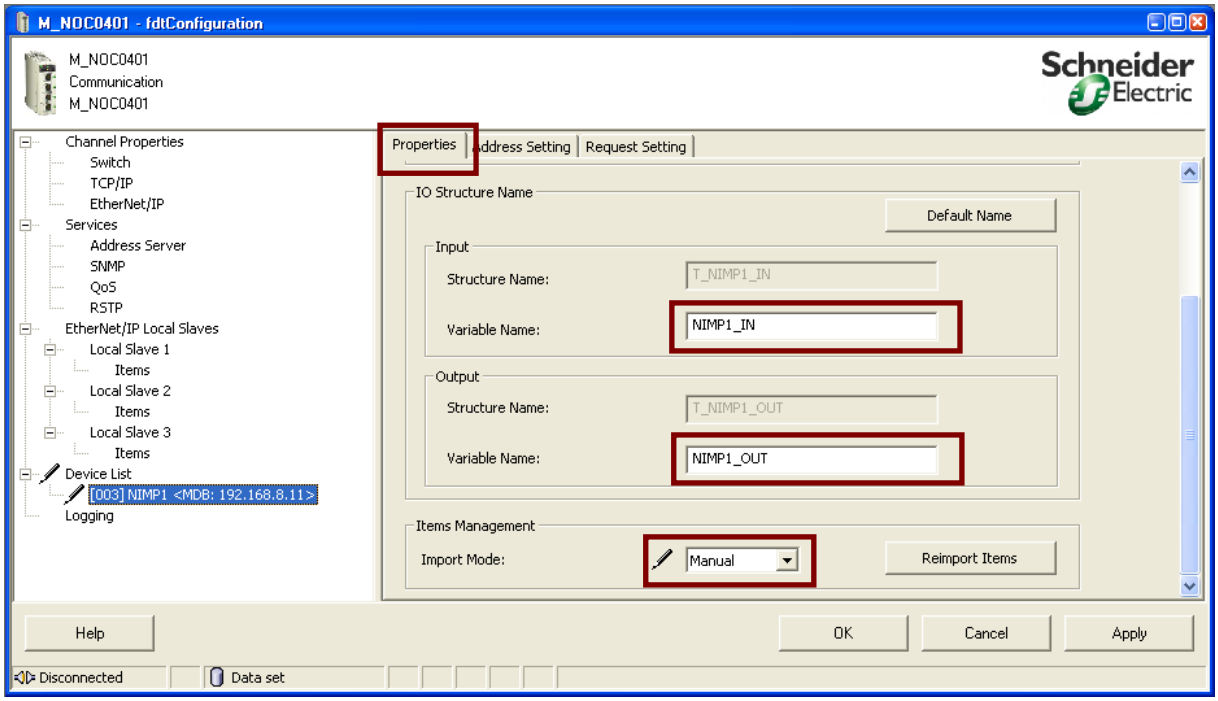
From the listed devices select a **Modbus Device**.



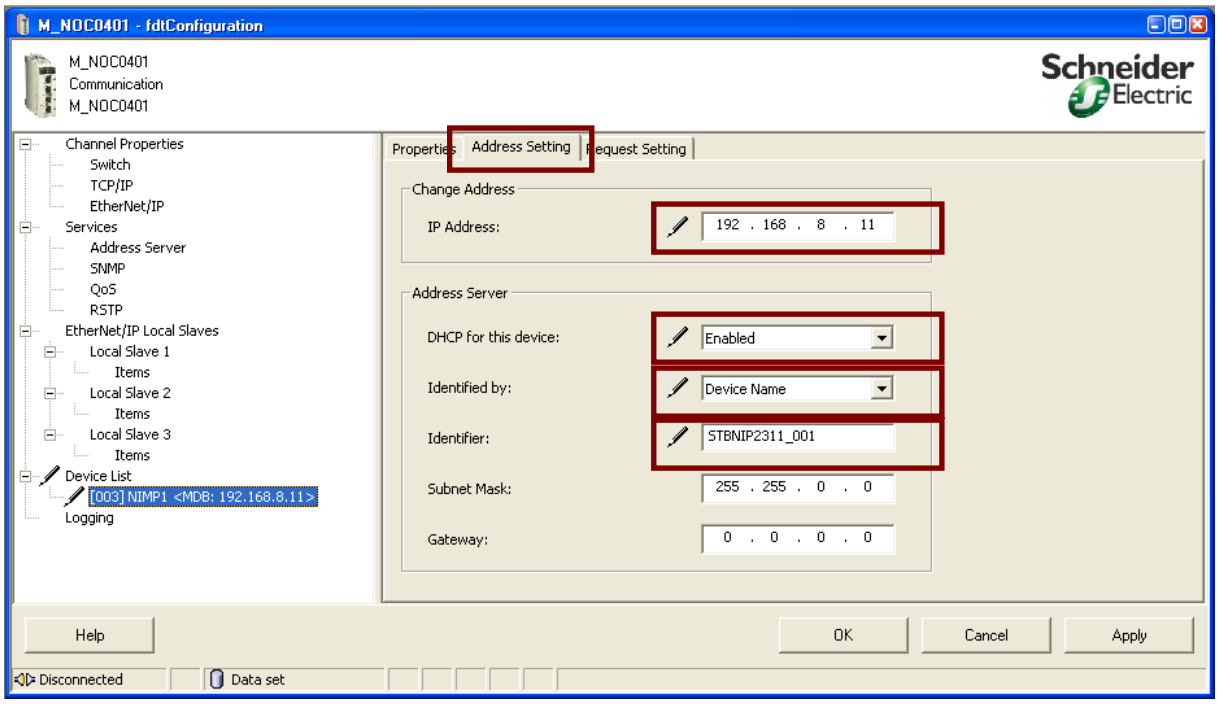
Provide an alias name to represent the device that is going to be controlled.



In the **Properties** tab, change **Items Management** import mode to **Manual**. This enables you to create user-defined variables.

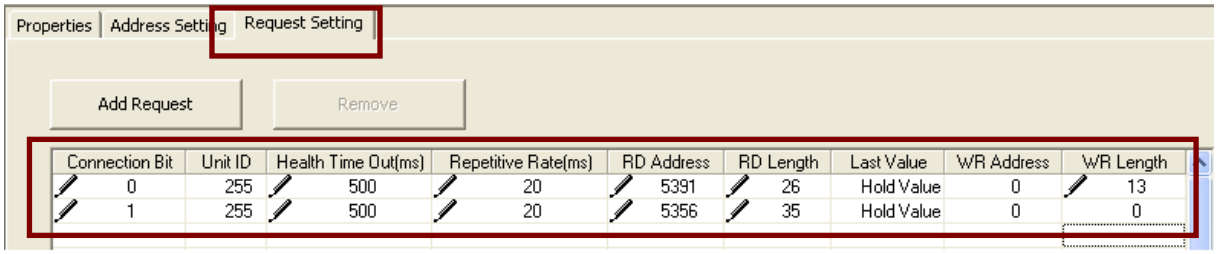


The rotary switches on the STB islands have been set up to use DHCP via the device name. The BMX NOC 0401 is also to be used as the address server in this standalone system. In the **Address Server** section, modify the following parameters: **IP address**, **DHCP Enabled**, **form of identification**, and the **device name for the Identifier**.

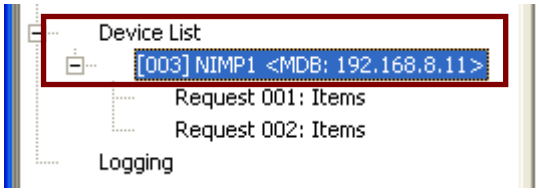


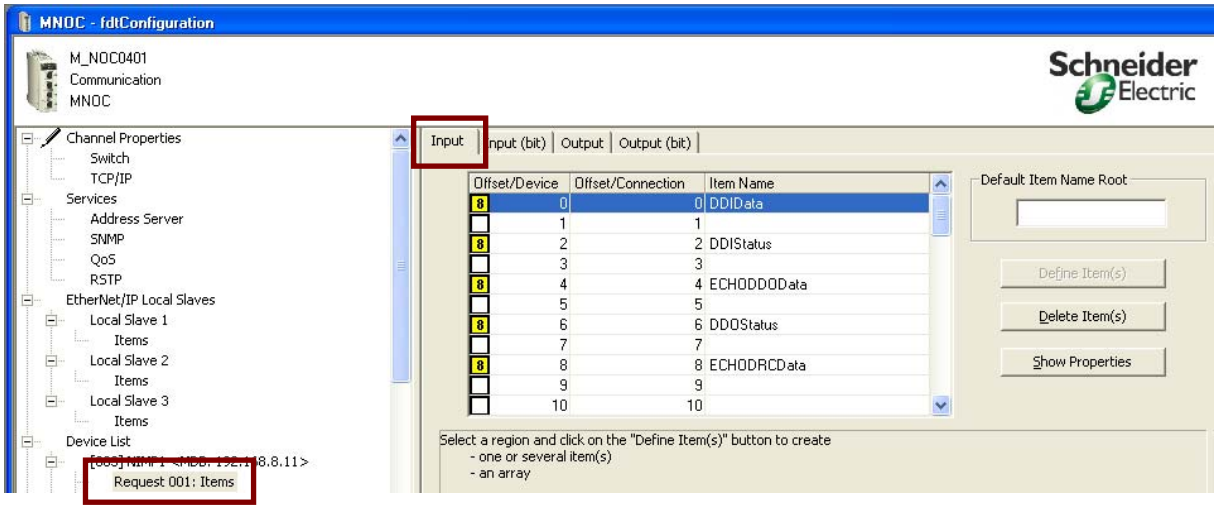
The **Request Setting** tab is used to configure read and write requests to the STB islands. Each STB island will have two requests: one for controlling and one to obtain STB island diagnostics at:

- a repetitive rate of 20 ms
- a health time out of 500 ms

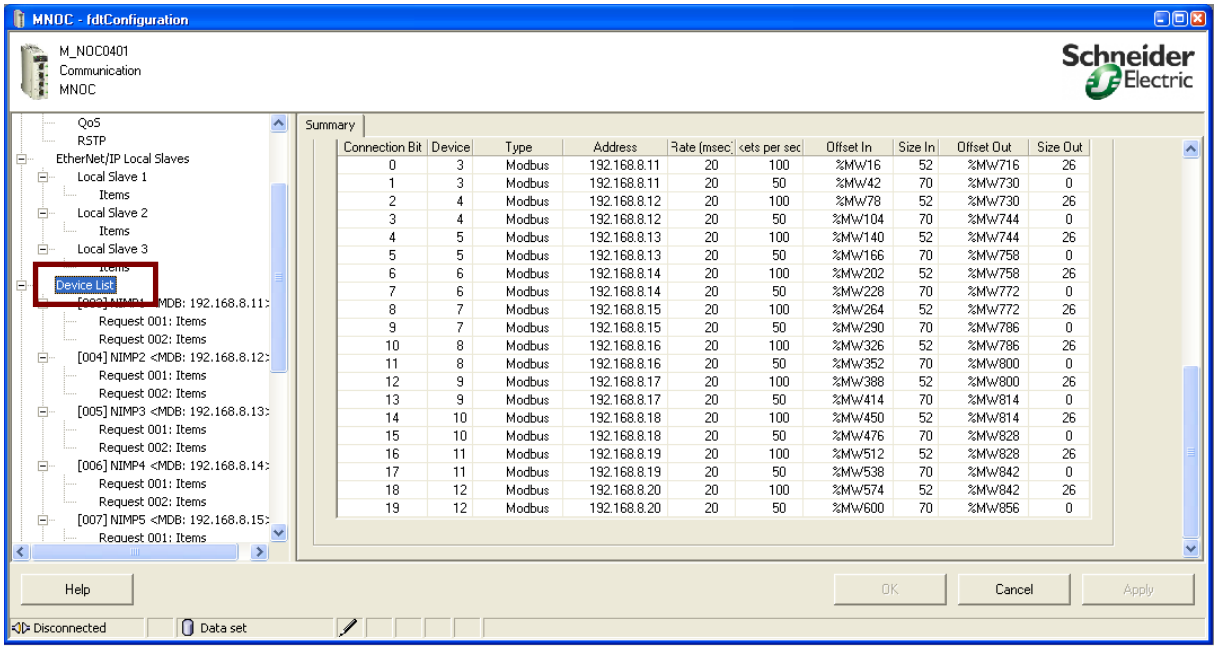


In the **Device List,** each request is itemized. Variables can be created for each request.

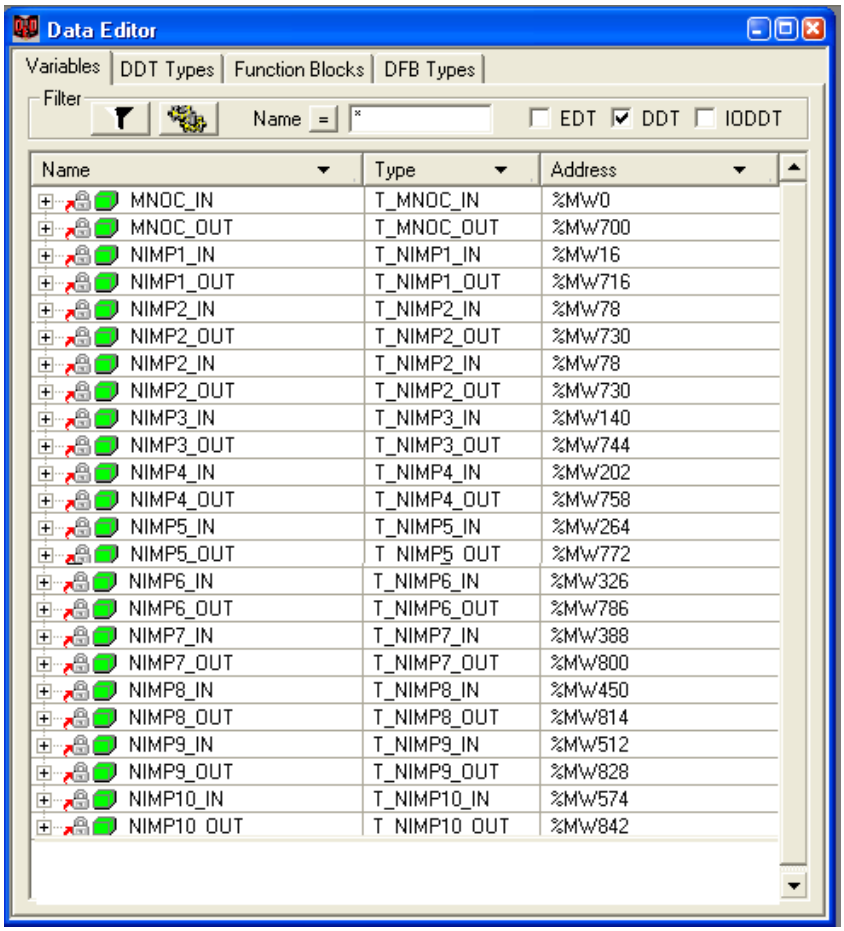




Add the other 9 devices by following the instructions above. When all the devices have been added, select **Device List** from the configuration screen. A summary is displayed of all the devices that are being scanned and their connections.

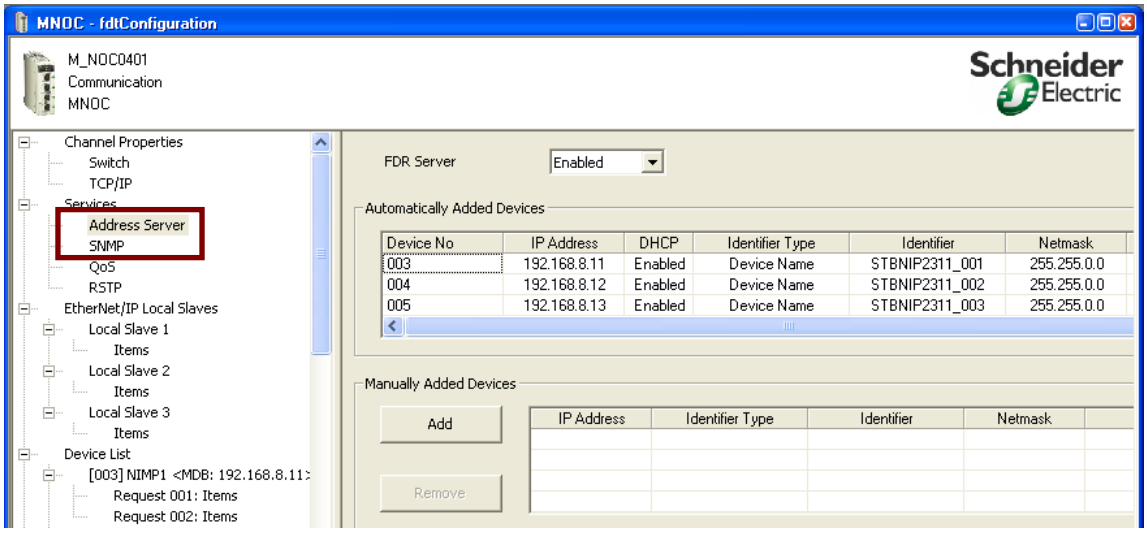

MNOC - fdtConfiguration
M_NOC0401
Communication
MNOC
Schneider Electric
QoS
RSTP
EtherNet/IP Local Slaves
Local Slave 1
Items
Local Slave 2
Items
Local Slave 3
Items
Device List
Request 001: Items
Request 002: Items
[004] NIMP2 <MDB: 192.168.8.12>
Request 001: Items
Request 002: Items
[005] NIMP3 <MDB: 192.168.8.13>
Request 001: Items
Request 002: Items
[006] NIMP4 <MDB: 192.168.8.14>
Request 001: Items
Request 002: Items
[007] NIMP5 <MDB: 192.168.8.15>
Request 001: Items
Summary
Connection Bit | Device | Type | Address | Rate (msec) | Packets per sec | Offset In | Size In | Offset Out | Size Out
0 3 Modbus 192.168.8.11 20 100 %MW16 52 %MW716 26
1 3 Modbus 192.168.8.11 20 50 %MW42 70 %MW730 0
2 4 Modbus 192.168.8.12 20 100 %MW78 52 %MW730 26
3 4 Modbus 192.168.8.12 20 50 %MW104 70 %MW744 0
4 5 Modbus 192.168.8.13 20 100 %MW140 52 %MW744 26
5 5 Modbus 192.168.8.13 20 50 %MW166 70 %MW758 0
6 6 Modbus 192.168.8.14 20 100 %MW202 52 %MW758 26
7 6 Modbus 192.168.8.14 20 50 %MW228 70 %MW772 0
8 7 Modbus 192.168.8.15 20 100 %MW264 52 %MW772 26
9 7 Modbus 192.168.8.15 20 50 %MW290 70 %MW786 0
10 8 Modbus 192.168.8.16 20 100 %MW326 52 %MW786 26
11 8 Modbus 192.168.8.16 20 50 %MW352 70 %MW800 0
12 9 Modbus 192.168.8.17 20 100 %MW388 52 %MW800 26
13 9 Modbus 192.168.8.17 20 50 %MW414 70 %MW814 0
14 10 Modbus 192.168.8.18 20 100 %MW450 52 %MW814 26
15 10 Modbus 192.168.8.18 20 50 %MW476 70 %MW828 0
16 11 Modbus 192.168.8.19 20 100 %MW512 52 %MW828 26
17 11 Modbus 192.168.8.19 20 50 %MW538 70 %MW842 0
18 12 Modbus 192.168.8.20 20 100 %MW574 52 %MW842 26
19 12 Modbus 192.168.8.20 20 50 %MW600 70 %MW856 0
Help
OK
Cancel
Apply
Disconnected
Data set

The BMX NOC 0401 configuration is now complete and ready to be built. From the Unity Pro **Project Browser**, double click the BMX NOC 0401 module in the rack, then click **Update application**. A set of derived variables is created; these variables can be used in the PLC logic.



4.1.2.3 Address server

The **Address Server** selection from the **Services** menu displays the devices for which the M340 Ethernet module is the DHCP/FDR server. Devices that are part of the M340 Ethernet module's configuration and have been configured for DHCP are listed in this screen. You can manually add other devices that are not being scanned separately.

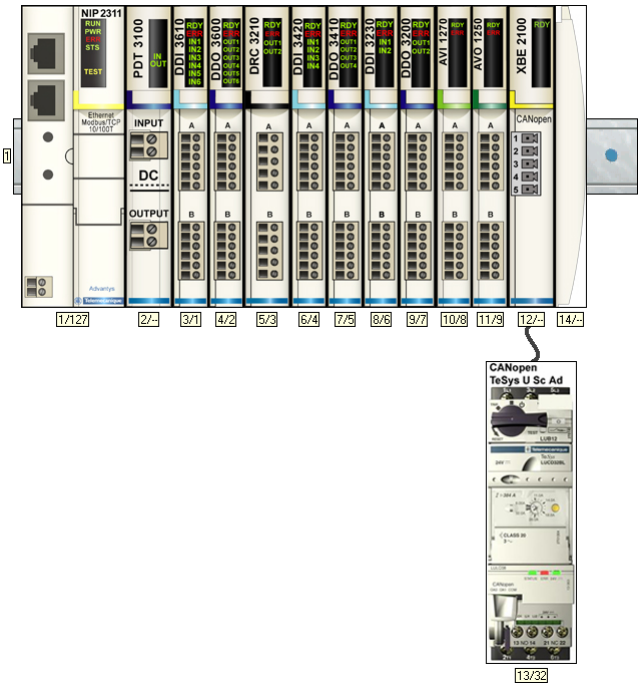


4.2. STB dual port Ethernet module for Modbus TCP

The Advantys Configuration Software is used to configure each island as follows:

1. Create a new workplace and add a new island.
2. From the Catalog Browser, expand **STB Catalog, Networking** and choose STB NIP 2311 v3.xx and drag it to the leftmost position on the island bus. This revision of the STB Ethernet network interface module supports RSTP.
3. Add the remaining power distribution and I/O modules. Place an island bus extension module as the last module on the island rack.
4. An island bus extension module must be the last module on the island rack. From the Catalog Browser, expand the **Accessories** folder and choose STB XBE 2100 v1.xx and drag it to the leftmost position in the next island rack.
5. From the Catalog Browser, expand the **Enhanced CANopen** folder and choose CANopen TeSys U Sc Ad- v1.xx. You can define some configuration parameters such as fallback strategy and the labels/variables by double clicking on the TeSys U module.

Note: An STB island that includes a CANopen bus extension in its configuration cannot be uploaded from the device to the software.



6. The last parameter that must be set is the baud rate. In the Advantys Configuration Software, choose the **Island** pull-down menu from the tool bar, select **Baud Rate Tuning** , and set the baud rate to 500 kbps.

7. The configuration is now ready to build and download to the STB island. You can download either via Ethernet or through a Modbus serial cable.

Note: Due to the CANopen bus extension, the RST button on front of the STB NIP 2311 module cannot be used to autoconfigure the island using default settings for all modules.

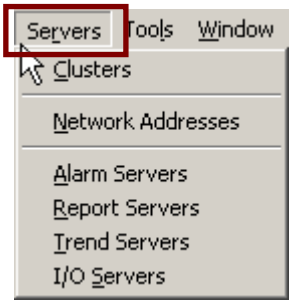
4.3. Vijeo Citect

The Vijeo Citect software is Schneider Electric's preferred SCADA system. Typically for a small system, SCADA redundancy is not required. In our implementation, therefore, all the servers will reside on one PC.

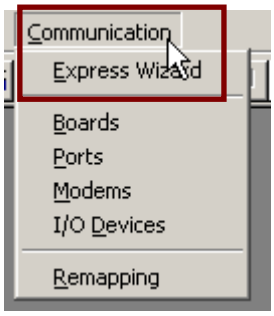
Start a new project within Citect Explorer. The basic SCADA configuration comprises two procedures, as follows:

4.3.1. Configuring SCADA parameters

1. From the **Citect Project Editor**, choose the **Servers** pull-down menu, and create the system's cluster, network addresses, alarm servers, report servers, trend servers, and I/O servers.

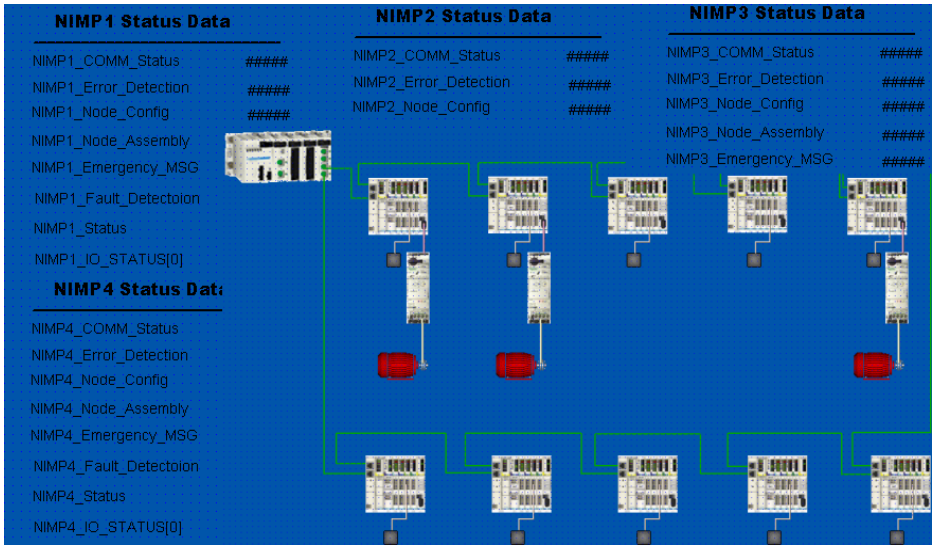


2. From the **Communication** pull-down menu, launch the **Express Wizard the wizard will s**et up: the boards, ports, and I/O devices. Be sure to select **TCP/IP** as the board type and **MODNET** as the protocol so that all requests will use Modbus TCP as the protocol.



3. You may use the **Citect Graphics Builder** to create pages for this system. In order to have write access from the SCADA system to the PLC, a user with full privilege must be created prior to running the project.

4. Create several graphical pages to represent the I/O system, and use them to verify communications and see the status information of I/O devices in the architecture. These pages enable a user to observe and control the state of the STB I/O from the M340 Ethernet Communication module.



4.3.2. Importing Unity Pro variables into Vijeo Citect Software

1. From the **Citect Project Explorer,** choose the **Tools** pull-down menu and point to the location of the *.XSY file that contains the exported variables from Unity Pro software.
2. Pack the data that you want to pass to the SCADA in contiguous memory locations. This is a matter of good practice ,because when SCADA is polling the PLC for the register data over a Modbus TCP connection, it can optimize its performance by sending requests in blocks of 125 registers. This project has 625 tags in contiguous registers that are being polled by the SCADA system.
3. Compile the project and run the **Computer Setup Wizard**. Some of the parameters that are identified include the network model, the startup functions, and the page scan time. For this project the page scan time is set to 250 ms.

4.4. Validating the system

Now that all devices are configured and the SCADA system is ready, the system can be validated. The tests are done in a building block manner, where the system is tested without any added traffic or network interruptions. Once a baseline is obtained, other conditions are introduced, such as cable break or SCADA traffic, and new measurements are collected.

5. System validation

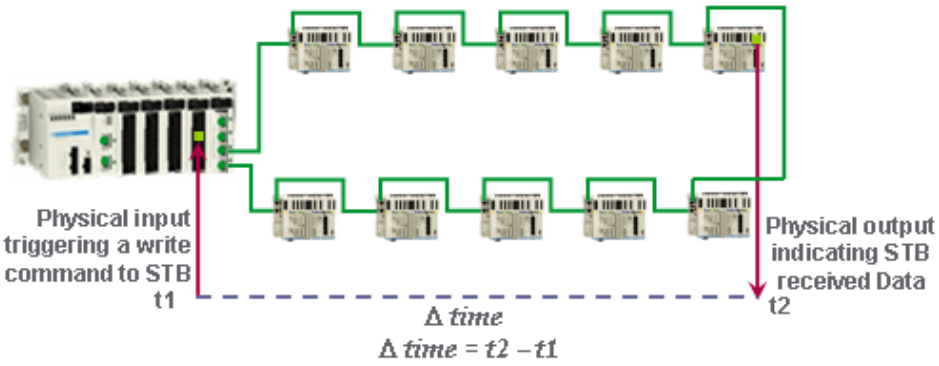
5.1. Introduction

One must know the feature set and performance requirements of a system in order to decide if it is a suitable system for the target application. It is just as important to know how the system behaves when exposed to stress. Particularly, does it recover from a fault and if so how fast? This section depicts various tests performed on the small I/O system followed by the results.

5.2 Application response time (ART)

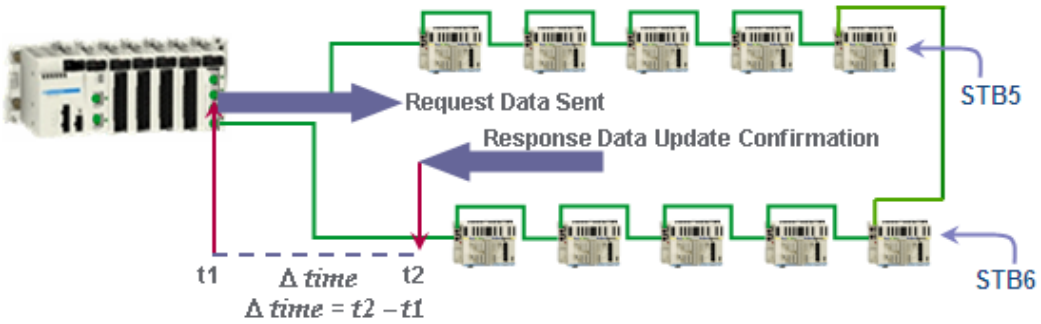
Two values are measured for ART to provide two different aspects of performance. The response times were measured two ways:

- **External ART:** measured from the time a *physical signal* in the M340 PLC turns on and triggers a write command to an STB island until the island's Vdc output relay turns on to signify that the data has been received.



External Application Response Time

- **Internal ART:** evaluates the time from when the request for write command is issued by the PLC to when the PLC receives status back from an STB island that data has been updated. Internal ART is meant to assist the user is gauging expected results for controlling devices in an RSTP network.



Internal Application Response Time

- In a system performance test, both external and internal ART are measured for an individual STB island and then repeated as a system for all 10 STB islands. Results can be used to establish the response time for the entire field of devices in the network.
- As mentioned previously, there are two data paths in the RSTP network. Messages are sent from both port 3 and port 4 of the M340 Ethernet module, placing the blocked link between STB5 and STB6. The measurement of internal and external ART for all devices is done by evaluating data sent from the M034 Ethernet module and update confirmation response is received by STB5.

5.2.1. Application response time test results

- ART measurements were taken from a representative system built according to the contents of this guide. The table below will summarize the findings for a quick overview. The results shown below are for more than 1000 samples.

Response Time	Single STB Island	All STB Islands
Minimum (ms)	119	122
Average (ms)	159	162
Maximum (ms)	196	198

Table 7. External ART Results

Graphs of the test results can be found in Section 6, Performance Results - Graphical results of External ART.

Response Time	Single Advantys STB	All Advantys STB
Minimum (ms)	162	163
Average (ms)	178	222
Maximum (ms)	224	275

Table 8. Internal ART Results

5.3. Power cycles

As part of the common operation in a plant, devices will experience power cycles. We conducted a test to evaluate the time taken for either a single or all the STB islands to regain communications with the M340 Ethernet communication module after they were powered on. Over a 1000 samples were measured for a single island and over 500 samples were measured for power cycling all STB islands.

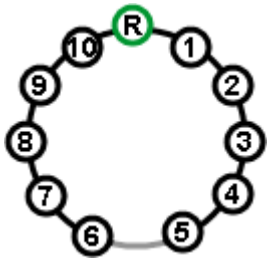
Recovery time	Single STB Island	All STB Islands
Minimum (sec)	18	32
Average (sec)	19	43
Maximum (sec)	28	53

Table 9. Power Cycle Test Results

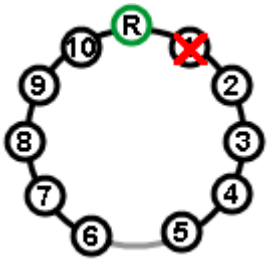
Graphs of the test results can be found in Section 6, Performance Results - Graphical Results for Power Cycle

5.3.1. Effects of network reconvergence on ART

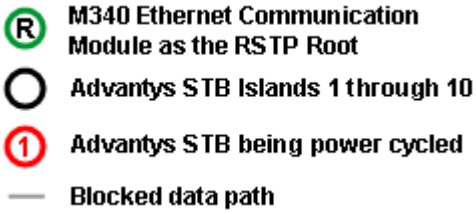
As an additional performance check, we measured the ART for the device adjacent to the affected device during power cycling of a single STB island. For this small I/O network, the worst-case scenario would be to power cycle device 1(the device closest to the root bridge) and measure the effects of the network reconvergence by measuring device 2's ART.



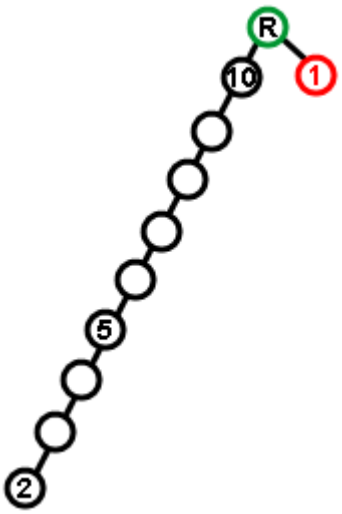
Normal RSTP Path



Device 1 being power cycled


R
M340 Ethernet Communication Module as the RSTP Root
Advantys STB Islands 1 through 10
1
Advantys STB being power cycled
Blocked data path

Because device 1 is no longer able to pass the messages to the devices down stream, the M340 Ethernet communication module must reroute the packets all the way around the daisy chain loop. In the graphic below the logical representation of the data path is shown. By comparing the ART of a single STB island to the ART of STB2 obtained during the above power cycle test, one can observe the network convergence effects on communication. This validates the network architecture chosen for the small I/O system.



Logical representation of re-converged RSTP data path

The table below shows that the network convergence on communication loss and recovery has no effect on the ART.

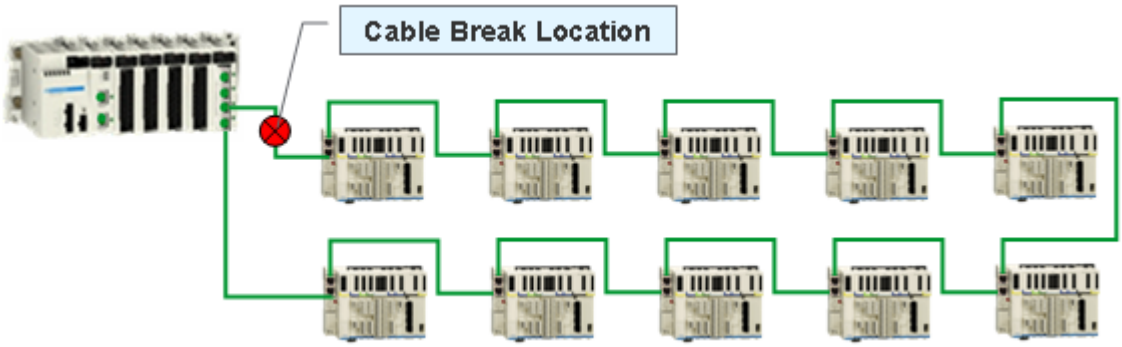
Response time	STB 2
Minimum (ms)	119
Average (ms)	158
Maximum (ms)	198

Table 10. External ART for a device failure recovery

Graphs of the test results can be found in Section 6, Performance Results – Effects of Network Re-convergence on ART

5.4. Infrastructure redundancy

The overall system integrity can be affected by many events such as; cable breaks between devices or an inoperable device. A cable break test was conducted to simulate an event that would result in a network reconvergence. Similar to the power cycle test, the worst-case scenario was chosen as the spot to break the cable link.



Simulated Cable Break Test

The External ART was measured during the test to validate the network's integrity. The ART remained typical with no significant variance.

Minimum ART	Average ART	Maximum ART
122 (ms)	159 (ms)	202 (ms)

Table 11. External ART for all islands after cable break

Graphs of the test results can be found in Section6, Performance Results – Effects of Network Re-convergence on ART

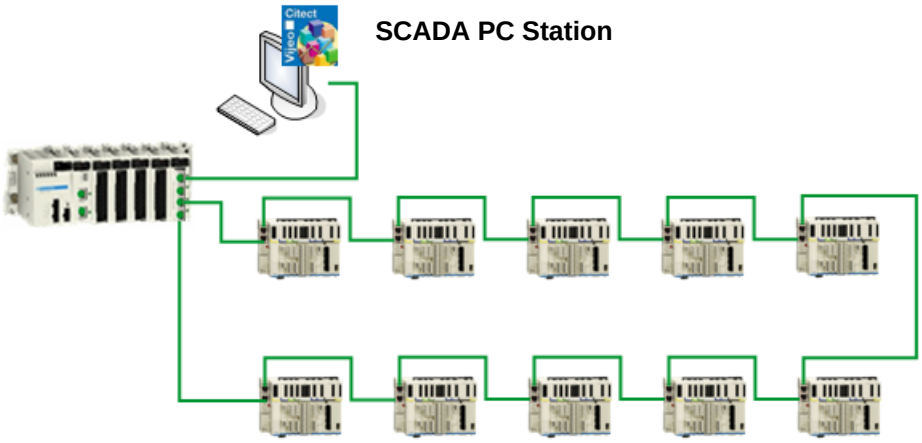
No effects were seen by the simulation test because of the speed at which RSTP resolves the topology after the cable was broken. A specialized tool revealed that for the small I/O system under test the RSTP ring was fully converged in less than 10 ms.

5.5. SCADA test

When it comes to SCADA, a few topics are of common concern:

- What effects will the SCADA traffic have on the network?
- What is the typical page update time?
- What is the longest time without data update during loss of communication?

In this system, the M340 Ethernet communication module also handles the SCADA traffic. Hence, it is important that the added task doesn't have any effects on the ART.

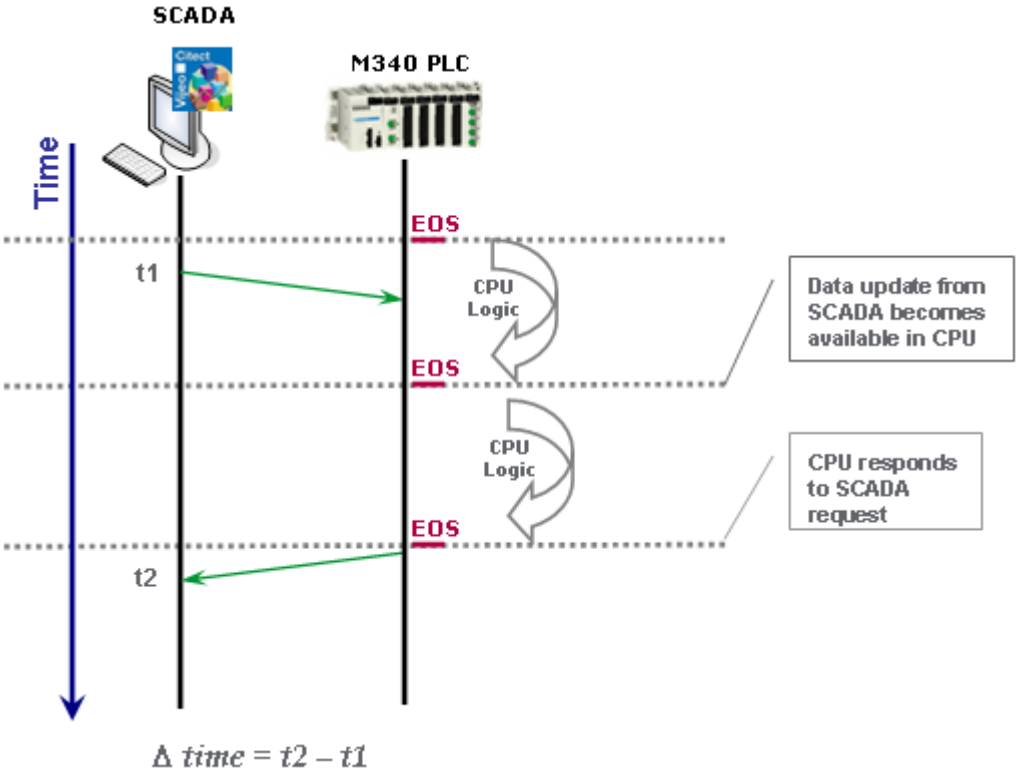


SCADA PC Station Location on the Network

Sample tests were conducted to answer these questions. The final solution may result in tuning certain parameters to obtain the best result for SCADA without affecting the system's ART.

5.5.1. Citect SCADA application response time

SCADA Client to PLC ART evaluates the time from when the SCADA Client writes a value to the PLC, until the PLC receives and returns that value to the SCADA Client. The Citect SCADA Client then measures and calculates the time it took to complete the request.



SCADA Client to PLC Application Response Time

While running the SCADA with all the default settings, we took measurements to obtain screen update time. From the 1000 samples tested, the *majority* of SCADA screen update times varied from 200 ms to 360 ms with one measured as long as 520 ms. The data shows that at times more than 10 CPU scans are required to obtain all the data from PLC. Even though the update time is less than 1 second, the performance can be improved significantly by modifying a few parameters.

Minimum (ms)	Average (ms)	Maximum (ms)
40	202	520

Table 12. Citect SCADA ART

Graphs of the test results can be found in Section 6, Performance Results – SCADA ART

To improve the performance of the SCADA, a few parameters were modified. In order to increase the number of requests sent to the I/O device, it is essential to know how many Modbus requests the communication module can handle simultaneously. The M340 Ethernet communication module can handle up to 8 Modbus requests prior to queuing them.

The following parameters were added to the MODNET driver section using the **Computer Setup Editor**.

- MaxOutstanding = 8
- MaxPending = 10
- AccumulateTime = 0

MaxOutstanding is the number of Modbus requests sent out simultaneously to the I/O device. *MaxPending* is the number of requests that can be pending a response from the I/O device. *AccumulateTime* is the waiting time before sending out a request once a response is received. For more information, refer to the Vijeo Citect help files.

With the above parameters set, the SCADA update time now takes fraction of the time update all the values. All five requests were sent to the M340 Ethernet Communication module simultaneously. This adjustment improved the SCADA update time significantly.

Minimum (ms)	Average (ms)	Maximum (ms)
40	59	80

Table 13. SCADA Screen Update Time Tuned for Performance

Graphs of the test results can be found in Section 6, Performance Results – SCADA Screen Update Tuned for Performance

Note: In systems that are not standalone, it is good practice not to use all server connections for SCADA usage. A few connections should be reserved for other explicit messages.

5.5.2. The effect of SCADA traffic on ART

In this small standalone I/O system, the SCADA generates 5 requests to the PLC. The data is setup to be updated every second. The results shown are for over 500 samples.

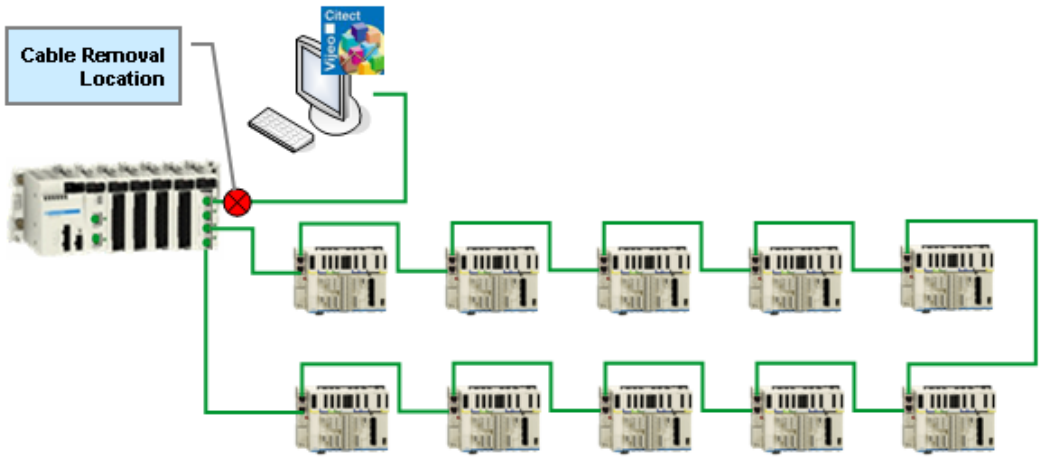
Minimum ART	Average ART	Maximum ART
128 (ms)	165 (ms)	201(ms)

Table 14. SCADA traffic effect on ART

Graphs of the test results can be found in Section 6, Performance Results - System ART with SCADA Traffic

5.5.3. SCADA-to-communication module cable break

A simulated cable break in the plant was performed to measure the communication recovery time. The time is measured from when the cable is reinserted in the M340 Ethernet Communication module until data is updated on the SCADA page. The updating of data indicates that communications have been reestablished.



Cable Removal at Communication Module Node

Minimum (s)	Average (s)	Maximum (s)
8	22	31

Table 15. SCADA to COMM Module Cable Break

Graphs of the test results can be found in Section 6, Performance Results - SCADA Cable Break

5.5.4. M340 Ethernet communication module replacement

We also measured the SCADA update time when the BMX NOC 0401 was reseated in the PLC rack. The time was measured from when the module was reseated until communications were restored.

Minimum (s)	Average (s)	Maximum (s)
33	53	96

Table 16. Recovery Time after M340 COMM Module Replacement

Graphs of the test results can be found in Section 6, Performance Results - M340 Ethernet Communication Module Replacement

5.5.5. SCADA update time when the M340 PLC rack is power-cycled

Another form of SCADA update time is to know the length of time it takes to reestablish communication after the rack has been powered on. The time is measured from the time the PLC rack's power is restored until data is displayed on the SCADA page.

Minimum (s)	Average (s)	Maximum (s)
34	49	60

Table 17. Communication Recovery Time after M340 PLC Rack Power Cycle

Graphs of the test results can be found in Section 6, Performance Results - M340 PLC Rack Power Cycle

5.5.6. SCADA recovery on page changes/refresh time

The validated results of refresh times when changing pages within the SCADA are recorded below. Screens were loaded with variable tags from all I/O devices so that an accurate generation of screen objects between pages could be observed.

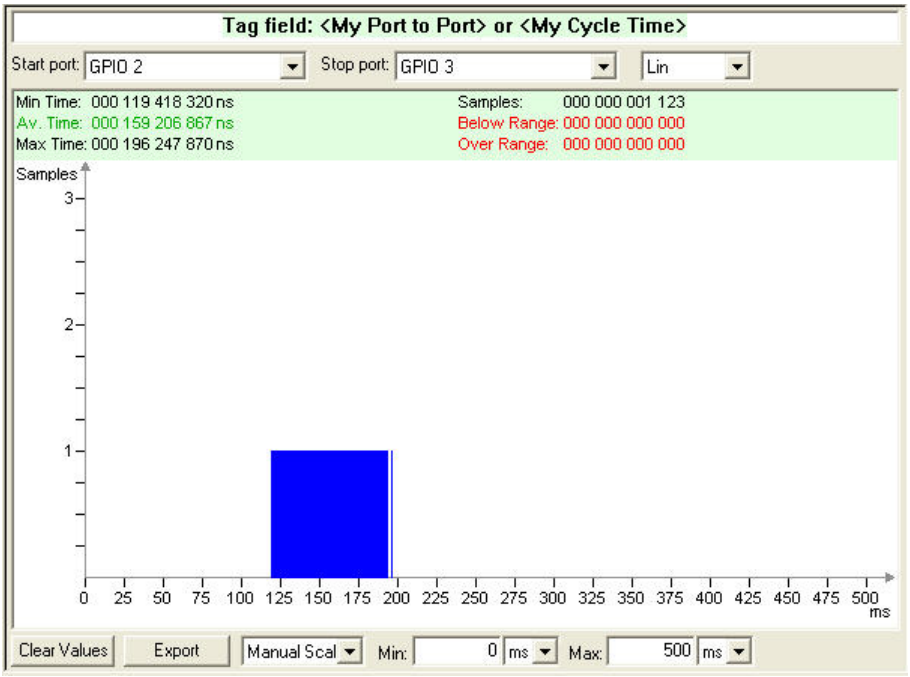
The following is the result of over 50 page changes to the SCADA client. During validation the SCADA client performed flawlessly and no interruptions to the communications were observed.

Minimum (s)	Average (s)	Maximum (s)
0	0	0

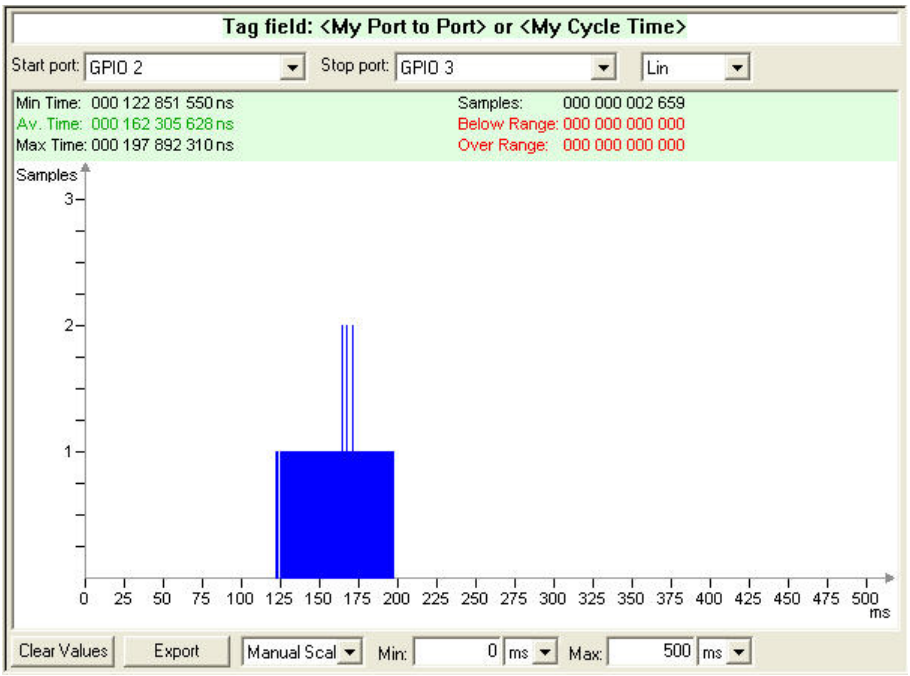
Table 18. SCADA Recovery on Page Changes

6. Performance results

6.1 External application response time

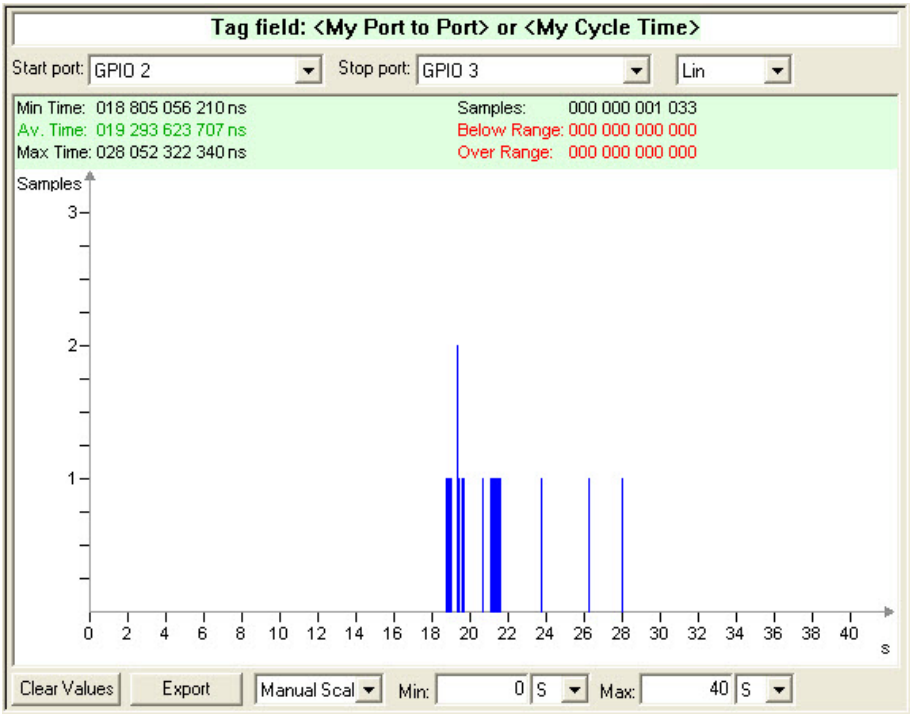


Graph 1. External ART: Single STB Island

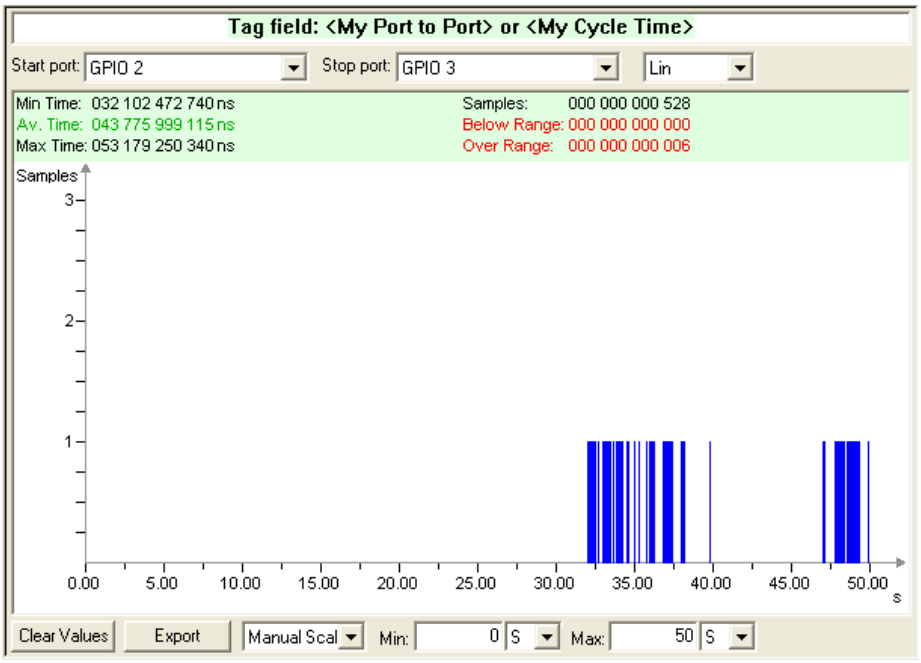


Graph 2. External ART: All STB Islands

6.2 Power cycle

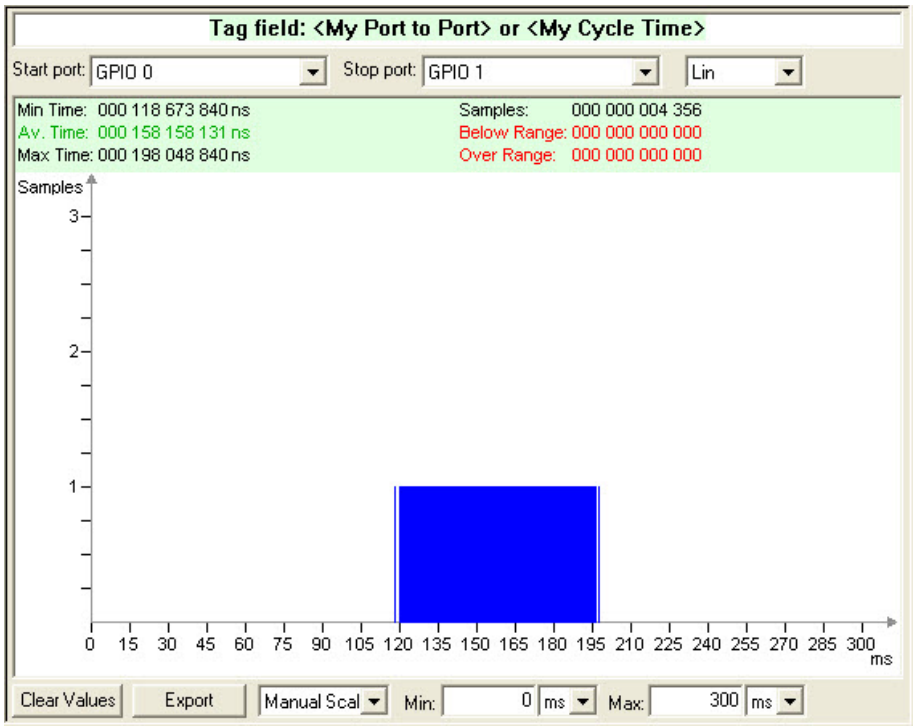

Tag field: <My Port to Port> or <My Cycle Time>
Start port: GPIO 2
Stop port: GPIO 3
Lin
Min Time: 018 805 056 210 ns
Av. Time: 019 293 623 707 ns
Max Time: 028 052 322 340 ns
Samples: 000 000 001 033
Below Range: 000 000 000 000
Over Range: 000 000 000 000
Samples
3
2
1
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
s
Clear Values
Export
Manual Scal
Min: 0 S
Max: 40 S

Graph 3. Power Cycle: Single STB Island

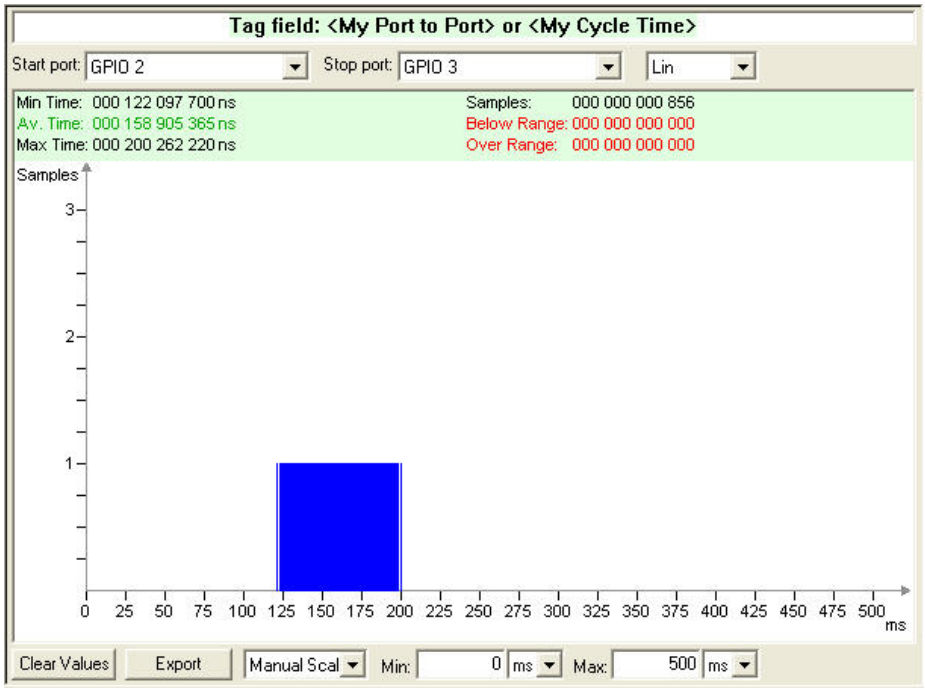


Graph 4. Power Cycle: All STB Islands

6.2.1. Effects of network reconvergence on ART



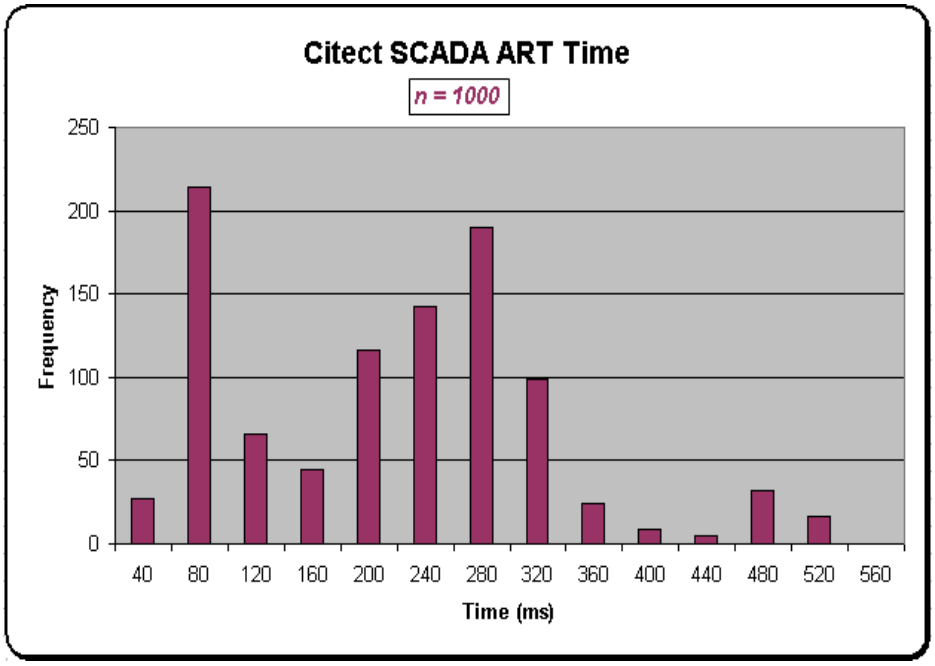
Graph 5. External ART for STB2 during Network Reconvergence



Graph 6. External ART for STB2 during Cable Break

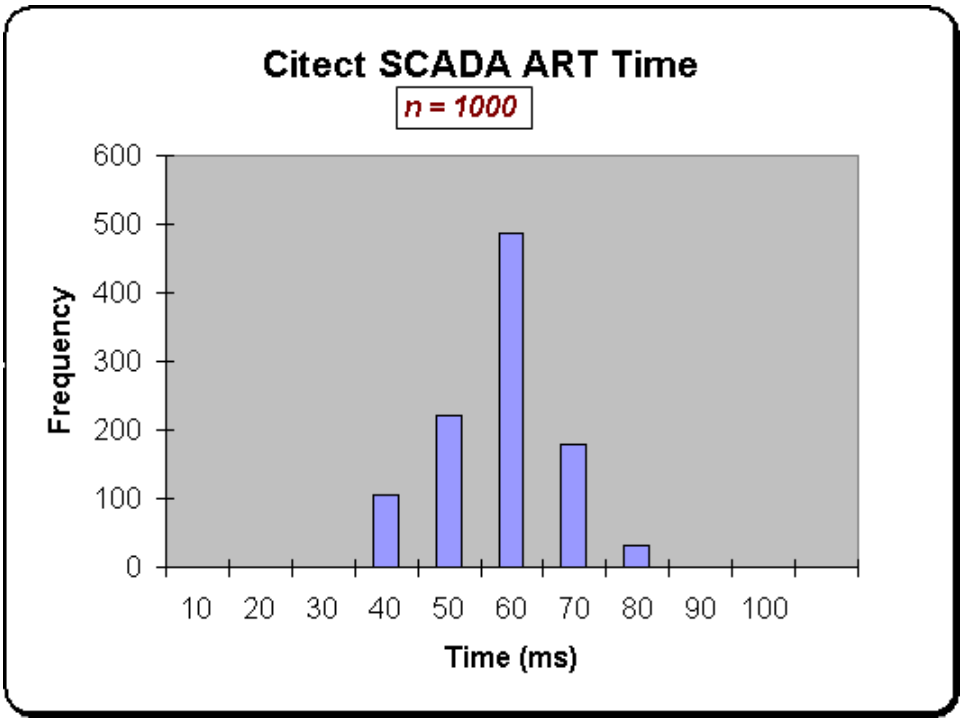
6.3. Citect SCADA screen update time

6.3.1. Citect SCADA ART – default settings



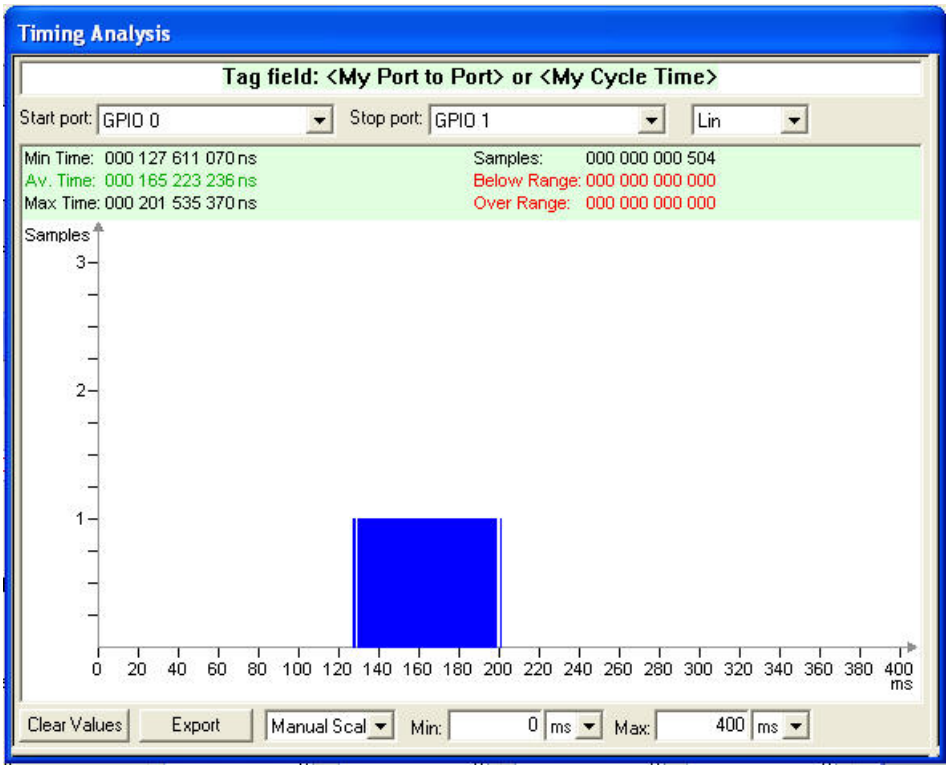
Graph 7. Citect SCADA ART: Default Settings

6.3.2. Citect SCADA ART – tuned for performance



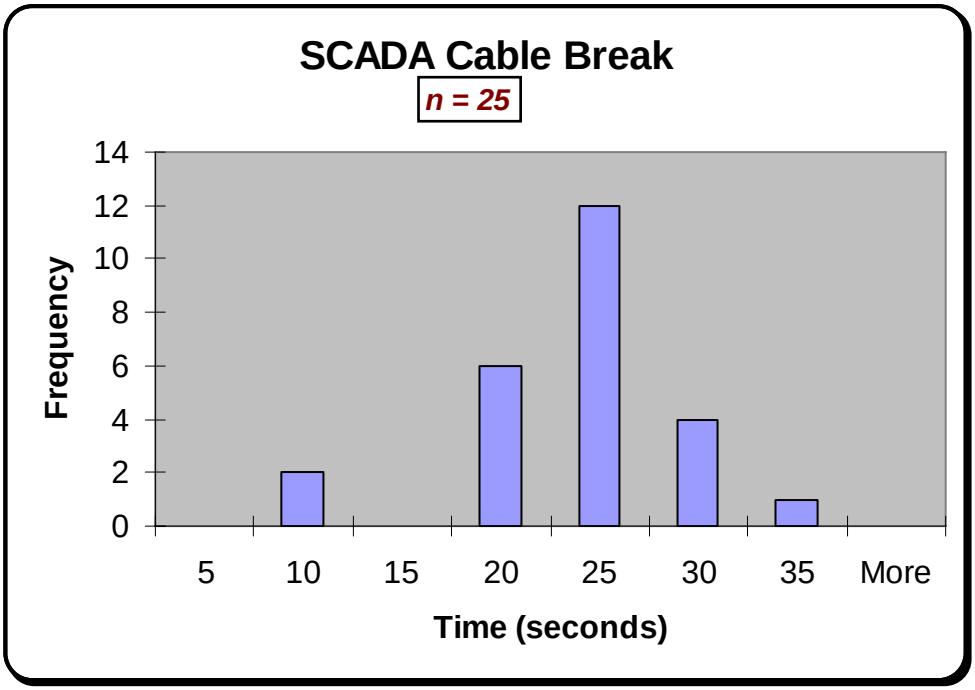
Graph 8. Citect SCADA ART: Modified for Performance

6.3.3. Effect of SCADA traffic on ART


Timing Analysis
Tag field: <My Port to Port> or <My Cycle Time>
Start port: GPIO 0
Stop port: GPIO 1
Lin
Min Time: 000 127 611 070 ns
Av. Time: 000 165 223 236 ns
Max Time: 000 201 535 370 ns
Samples: 000 000 000 504
Below Range: 000 000 000 000
Over Range: 000 000 000 000
Samples
3
2
1
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400
ms
Clear Values
Export
Manual Scal
Min: 0 ms
Max: 400 ms

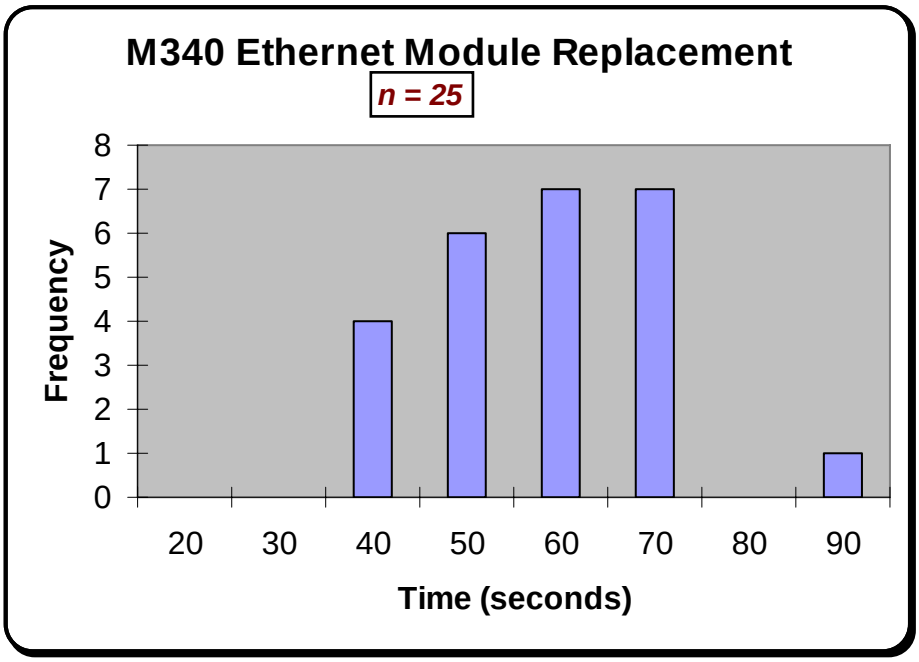
Graph 9. External ART with SCADA Traffic, NO Cache

6.3.4. SCADA Cable break



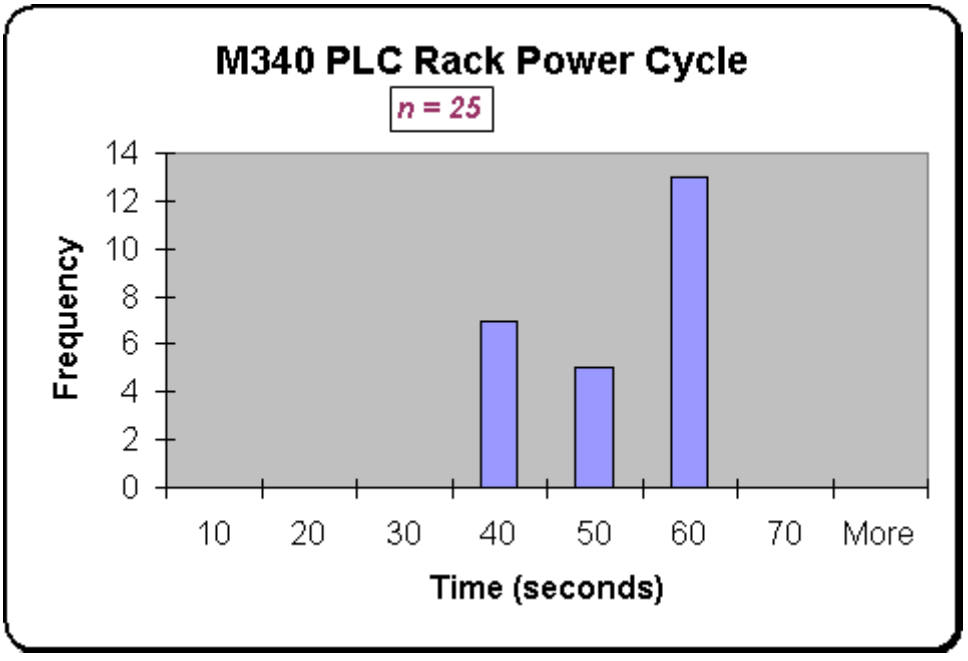
Graph 10. SCADA-to-BMX NOC 0401 Ethernet COMM Module

6.3.5. SCADA – M340 Ethernet communication module replacement



Graph 11. BMX NOC 0401 Replacement

6.3.6. SCADA: M340 rack power cycle



Graph 12. M340 Rack Power Cycle

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